BONUS! BINOCULAR BUYER'S GUIDE

ASTRONOMY®

November 1992
U.S. $2.95
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COSMIC ORIGINS OF LIFE ON EARTH

Odd-Couple Galaxies

Mars: How to See the Most this Winter

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Did Impacts Help Start Life on Earth?

MEADE

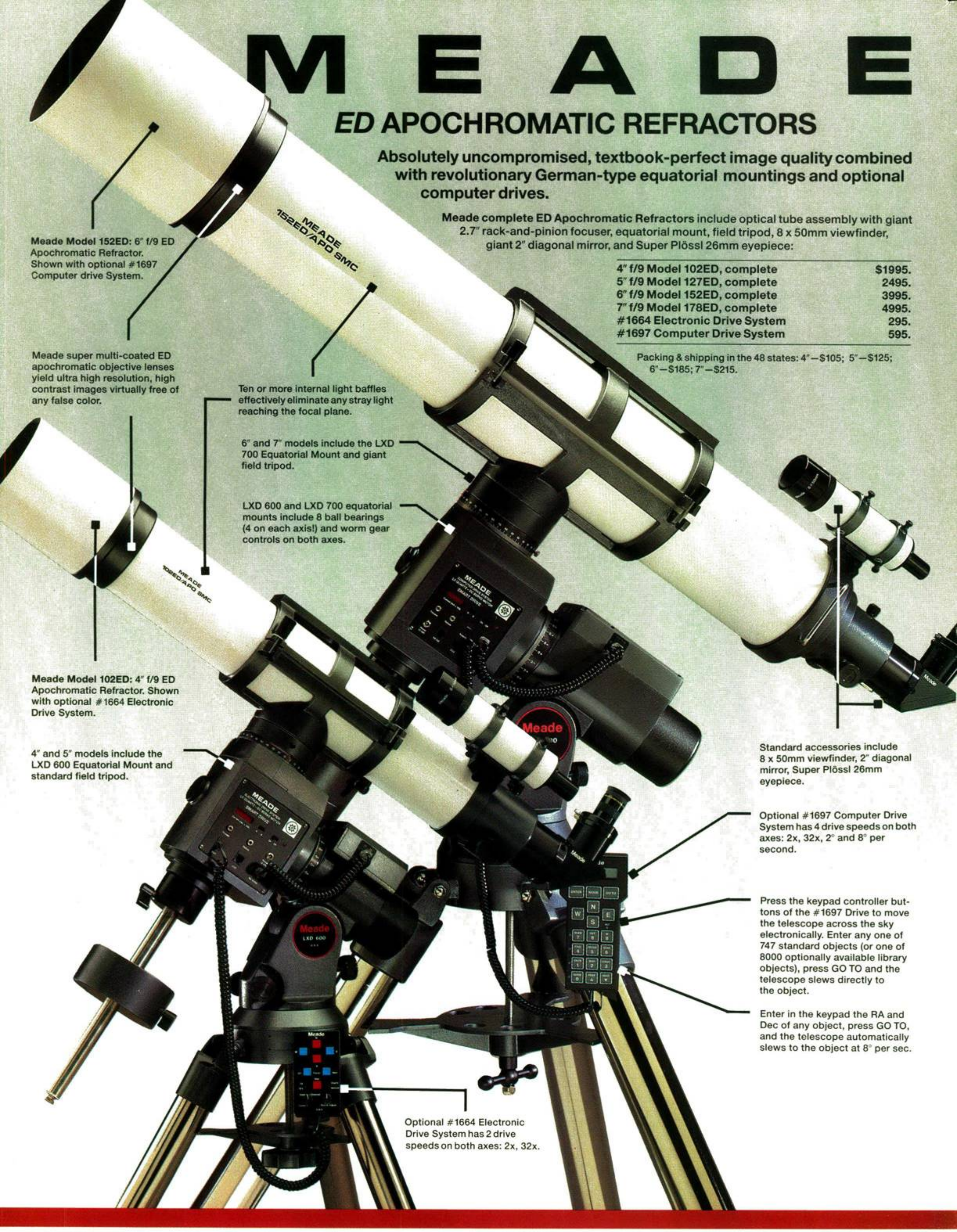
ED APOCHROMATIC REFRACTORS

Absolutely uncompromised, textbook-perfect image quality combined with revolutionary German-type equatorial mountings and optional computer drives.

Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7″ rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2″ diagonal mirror, and Super Plössl 26mm eyepiece:

4″ f/9 Model 102ED, complete	**$1995.**
5″ f/9 Model 127ED, complete	**2495.**
6″ f/9 Model 152ED, complete	**3995.**
7″ f/9 Model 178ED, complete	**4995.**
#1664 Electronic Drive System	**295.**
#1697 Computer Drive System	**595.**

Packing & shipping in the 48 states: 4″—$105; 5″—$125; 6″—$185; 7″—$215.



Meade Model 152ED: 6″ f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer drive System.

Meade super multi-coated ED apochromatic objective lenses yield ultra high resolution, high contrast images virtually free of any false color.

Ten or more internal light baffles effectively eliminate any stray light reaching the focal plane.

6″ and 7″ models include the LXD 700 Equatorial Mount and giant field tripod.

LXD 600 and LXD 700 equatorial mounts include 8 ball bearings (4 on each axis!) and worm gear controls on both axes.

Meade Model 102ED: 4″ f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

4″ and 5″ models include the LXD 600 Equatorial Mount and standard field tripod.

Standard accessories include 8 x 50mm viewfinder, 2″ diagonal mirror, Super Plössl 26mm eyepiece.

Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.

Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

10″ Model 2120A: $1379.*

8″ Model 2080A: $1099.*

Meade Standard Series 8″ and 10″ SCT's: advanced technology at economical pricing levels.

No other comparably-priced Schmidt-Cassegrains offer the optical and mechanical features of the Meade Standard Series:

■ **Optics:** The World's most recommended and largest-selling Schmidt-Cassegrain optics, warranted to be the finest available from any manufacturer. Razor-sharp imaging through both 8″ and 10″ models. Standard Series 8″ and 10″ SC optics are the exact same as used on Meade LX200 models.

■ **Mountings:** Highly stable, low vibration fork mountings designed for advanced applications such as long-exposure astrophotography, mountings that can carry more than *twice the payload* of competing small German-type mounts.

■ **Standard-Equipment Motor Drive System:** Not an add-on, but *a built-in 5.75″ worm gear drive that is the most accurate available on any SCT in this price range.*

■ **Variable-Height All-Metal Field Tripods:** The finest tripods yet developed for SC telescopes, the ultimate in rigidity and low-damping time.

■ **Optional Systems:** Unlike competing German-mounted SCT's with small worm gears, Meade Standard Series SCT's permit almost unlimited growth potential—use the **#46 Dual-Axis Drive Corrector** for deep-space photography with the **Off-Axis Guider** system; **#929 2″ Diagonal** with 2″ **Super Wide Angle** eyepieces for breathtaking wide-field observing; and much more. ***See the Meade catalog for details!***

4″ Model 2045D: $599.*

4″ Model 2045D: the Ultraportable Meade SCT

For the beginning astronomer the lightweight and easy-to-use Meade 2045D packs a powerful potential for serious observing. As a second telescope for the advanced amateur, the 2045D permits wide-ranging observations in locations inaccessible or inconvenient to larger instruments. Each telescope includes optics manufactured to the same high performance standards as larger Meade models. The DC drive system operates from a micro battery pack for convenient field use. Full accessorization is available for virtually any field application.

Specifications: Model 2045D—Complete with 4″ f/10 Schmidt-Cassegrain tube assembly with super multi-coated optics; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 12-volt DC pulse motor, spur gear drive system; AA battery pack (batteries are not included); tabletop tripod system; eyepiece holder/diagonal prism; coated MA 25mm (40X) eyepiece (1.25″); 5 x 24mm viewfinder. . . . . **$599.**

Packing and shipping in the 48 states . . . . **$40.**

Specifications: 8″ Model 2080A—Complete with 8″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls and locks on both axes; 5.75″ worm gear motor drive system (115v./60Hz); eyepiece-holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 6 x 30mm viewfinder; equatorial wedge; variable-height all-metal field tripod. . . . . **$1099.**

Model 2080B—Identical to Model 2080A, but in addition with Super Multi-Coated optics. . . . . **$1149.**

Packing & shipping on either 8″ model in the 48 states: . **$95.**

Specifications: 10″ Model 2120A—Complete with 10″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75″ worm gear motor drive system (115v/60Hz); eyepiece holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 8 x 50mm viewfinder; equatorial wedge; variable-height all-metal field tripod. . . . . **$1379.**

Model 2120B—Identical to Model 2120A, but in addition with Super Multi-Coated optics. . . . . **$1449.**

Packing & shipping on either 10″ model in the 48 states: **$125.**

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☐ **For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, visit one of the hundreds of Meade dealer showroom locations throughout the USA; or contact one of the authorized mail-order dealers at left. Or call Meade Instruments toll-free at 1-800-854-7485 (in California 714-556-2291).**

☐ *All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

☐ The all-new **1992 Meade General Catalog**—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

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World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
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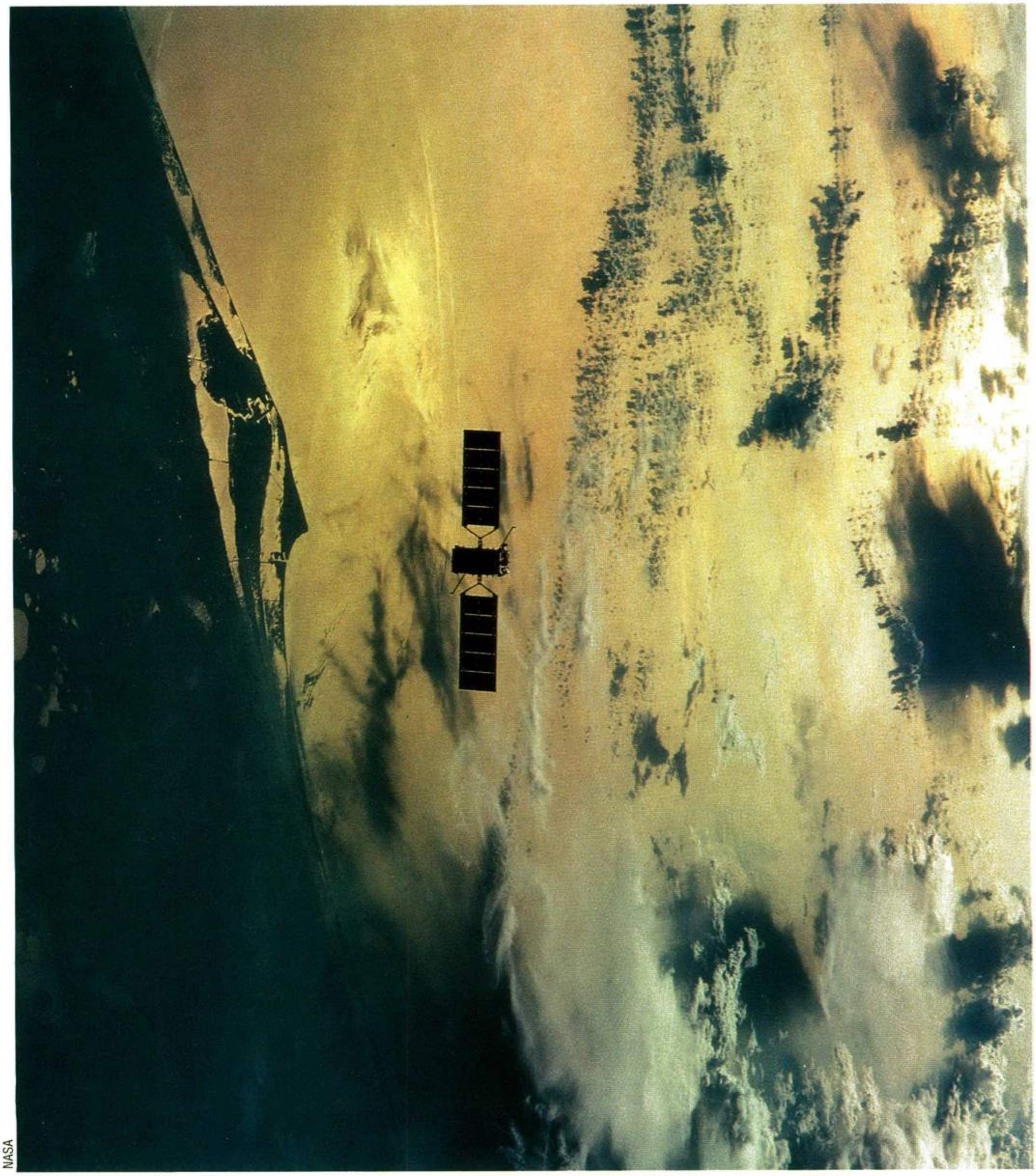
ON THE COVER: Four billion years ago, comets and meteors may have brought the ingredients for life to the newly formed Earth. To learn more, turn to page 28. Art by Robert Eggleton.

FLYING FREE over the coast of Florida is the European EURECA satellite, launched last August by the shuttle. See page 26 for a mission report.



NASA

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The Audit Bureau

Behind the Scenes

GETTING GOING IN ASTRONOMY

"Say, you're into astronomy, aren't you? What kind of telescope should I buy?"

Sound familiar? As the holidays approach, every backyard astronomer can count on being asked this many times. And unless you intend to hide out until the last fumes of New Year's eggnog have vanished, you'll have to answer it somehow.

When I've been asked, I've done what many probably do. I probe a little. Does the person have some kind of telescope in mind? What sort of objects do they want to see? And most important, what's the budget? The last question is really critical. What do you say to someone who wants a scope and has only $50 to spend? Perhaps the limit could stretch to $100, but that's absolute tops.

It's never an easy question to answer. Put on the spot, I often get the uncomfortable feeling that someone's entire astronomy future may depend on what I say. It's difficult to impossible to find a good telescope for $100, I tell them. Instead, why not try a pair of binoculars — 7x50s, for example? (To tell the truth, even if they had five times $50 to spend, I'd still recommend the 7x50s.) Binoculars don't look very astronomical, which sometimes seems important to newcomers. But because they provide a lot of easy-to-use viewing pleasure, binoculars get beginners into astronomy much faster than the fumble-and-grope routine that many go through with unfamiliar low-budget telescopes.

So we focused our buyer's guide this year (see the insert section) on binoculars useful for astronomy. When Alan Dyer came to me with the table he compiled, I was astonished at the variety of what's on the market. At every price level from $50 to well over $1,000, you'll find instruments that deliver nice fat exit pupils to dark-adapted eyes. Moreover, as every backyard astronomer knows, binoculars are essential hardware no matter what size telescope you have because they fill a unique niche in your observing equipment.

That goes for professionals too. On a visit to Kitt Peak observatory one night many years ago, I spied a pair of 7x50s in one of the domes. Suppressing a smile, I asked if they were to help locate objects. No, I was told, the telescope had a finderscope for that. Were they used so the observer at the instrument could check the control panel readouts? No again. Well, what were they used for, I pressed.

They were simply for looking at stars.

This dome was crammed with a big telescope carrying the latest in computerized detectors for cutting-edge research. And yet when the astronomers took a break from their work and stepped outside to look at the sky, the most natural and appropriate instrument to use was a pair of 7x50s.

Tell that to the next beginner who looks askance when you steer them to binoculars.

Sincerely,

Robert Burnham
Editor

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Letters

COBE's Big Bang

I was concerned to note that "COBE's Big Bang" (August 1992) did not mention the fundamental role played by NASA and its scientists in this mission. COBE (the Cosmic Background Explorer Satellite) is a NASA venture and the COBE team is made largely of scientists based at the Goddard Space Flight Center and coordinated from there.

Regarding the results, it's important to realize that the COBE data reveal statistically significant patterns of noise, not structure itself. In one particular sense, the by-now famous ripples are not "real." For example, if a duplicate COBE were launched tomorrow and it could map the sky precisely as the present COBE does, it would not observe the same pattern as shown in the diagram on page 42 of the August issue. It would probably find ripples, but their positions would not coincide with those mapped by COBE. — *Gerrit L. Verschuur, Lakeland, Tennessee*

A Return to the Future?

As I read Barry Parker's article "Tunnels through Time" (June 1992) it was comforting to remember that Einstein himself chuckled over the possibilities that his theories raised. Time travel was certainly prime among the chuckles. Einstein himself said that "time is of psychological origin, a subjective idea; an activity of the mind creating order."

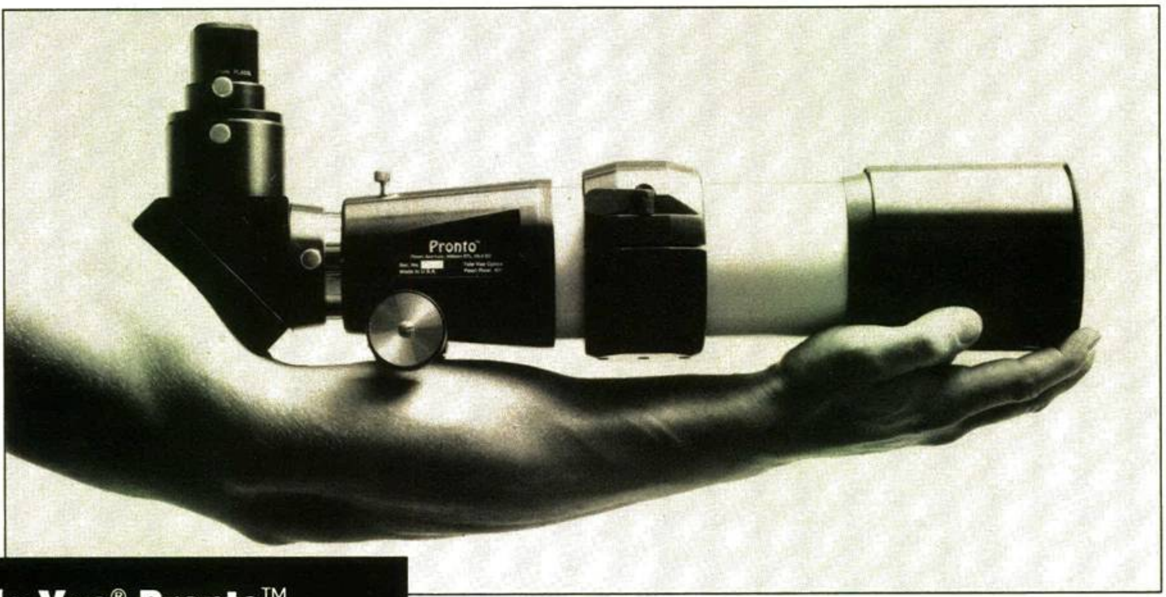
But the concept of time is seductive. Because we can use our minds to reconstruct former events — memories — we think we can reconstruct former times. While Einstein might approve of the black holes and wormholes as realities of science, he would not approve of calling time travel science. — *Ken Gunther, Jupiter, Florida*

Let us tackle the problem of building a craft and accelerating it toward Alpha Centauri before we attempt to find tunnels through time! — *Joseph Baldassano, Sr., Rockville, Maryland*

UNIVERSE 92 a Success

I would like to congratulate Astronomy and the Astronomical Society of the Pacific on their wonderful handling of the UNIVERSE 92 conference in Madison, Wisconsin (held on June 20-21, 1992). There seemed to be something for everyone. Each talk covered a different aspect of astronomy. For those who would say that not much diversity exists within amateur astronomy, I would point out that the talks had to be scheduled over two full days so they could all fit in!

PRONTO



Tele Vue® Pronto,™ The arm's length telescope that puts you just an arms length from your Universe

Pronto flexes its American muscle with a 70mm lens that powers you to brighter, sharper, and wider fields of view than any 60mm scope. With 36% more light gathering capability, higher resolution and fields of view as large as 11 full moon diameters across, Pronto's value is immediately clear the first time you look through it.

Al Nagler, President of Tele Vue, designed Pronto to bring you the kind of viewing experience he created for NASA space simulators. "Spacewalk" views of the rings of Saturn, cloud bands on Jupiter, lunar craters and mountains, galaxies, nebulae and beautiful Milky Way star clusters, are yours with Pronto's multi-coated, E.D. objective and optional "Nagler" eyepieces.

Full frame 35mm telephoto photography and an extraordinary 8x to 235x power range, is possible only with Pronto's standard 2" accessories. Mounts just like a camera to any tripod for instant, arm's length views from nesting birds to distant vistas on Earth and beyond.

Call us pronto to find out how quickly and easily you can experience Pronto's unique "picture window with magnification."

Features and Performance Beyond Compare:

Power Range: 8x to 235x available

Max. Field: 5.8° (304ft. @ 1000YDS)

Objective: 70mm E.D., diffraction limited

Telephoto Lens: 450mm f/6.4

Mounting: Attaches to photo tripods

Construction: Black anodized CNC machined aluminum, Chrome plated brass, Powder coated aluminum tube.

Features: 2" diagonal, 2" focuser, 2" to 1¼" adapter, sliding mount ring with lock, sliding dew-shield, threaded lens cover,

Eyepiece: 21mm Tele Vue Plössl (21x)

Case: Protective travel bag with shoulder strap

Warranty: 5 Years

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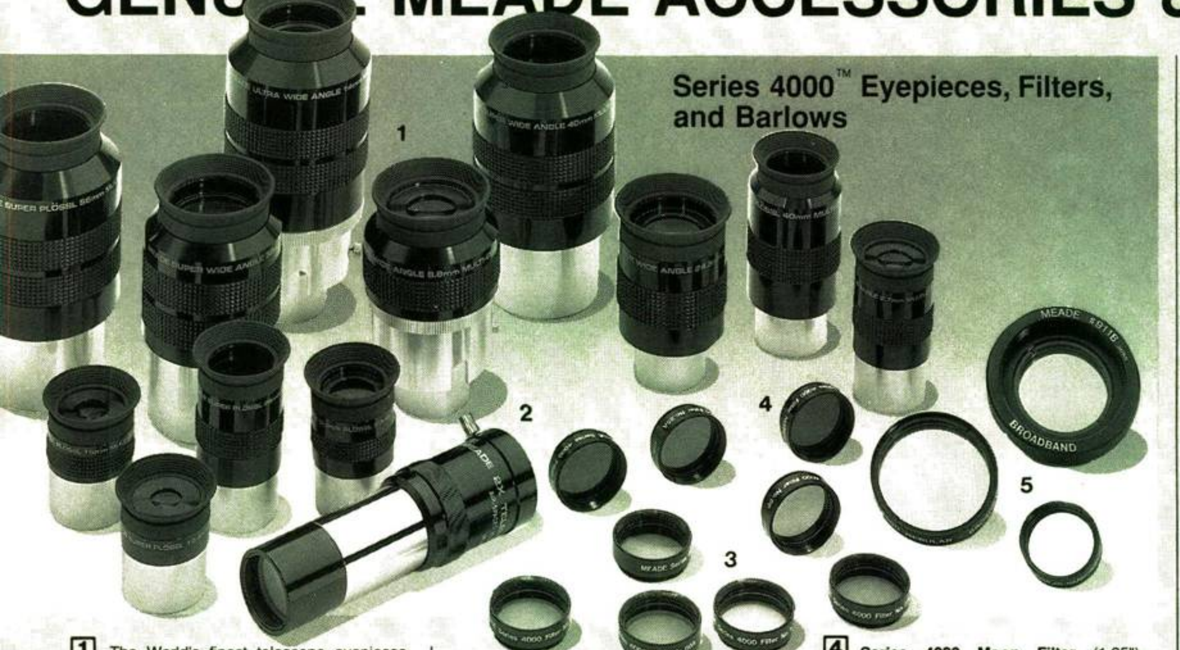

Series 4000™ Eyepieces, Filters, and Barlows

1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
6.4; 9.7; 12.4; 15; 20; 26mm ea **$79.95**(2.49)
32mm(52°); 40mm(44°); each **99.95**(2.49)
56mm (52°, 2") **219.95**(3.18)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm:129.95(2.49) **18mm:139.95**(2.49)
24.5mm:159.95(2.49) **32mm(2"):229.95**(3.18)
40mm(2"): 279.95 (3.18)

Ultra Wide Angles (8-elements, 1.25"; 84°):
4.7mm: 147.95 (2.49) **6.7mm: 187.95** (2.49)
8.8mm(1.25"/2"): 219.95 (3.18)
14mm(1.25"/2"): 249.95 (3.18)

*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$69.95** (2.49)

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each **$12.95** (1.79)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$42.95** (2.49)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$42.95** (2.49)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green . **$42.95** (2.49)

Sets #1 & #2—8 filters **$82.95** (2.49)

Sets #1, #2, & #3—12 filters **$118.95**(3.18)

4 **Series 4000 Moon Filter** (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$14.50** (2.49)

5 **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

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#908B (1.25")—Threads into all Meade 1.25" eyepieces, and virtually all other brands. Full 26mm clear aperture. **$67.95**(1.79)

#910B—Threads into all Meade 2" eyepieces and most others; 44mm dia. **99.95** (2.49)

#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **87.95** (1.79)

NARROWBAND FILTERS

#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95**(1.79)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95**(2.49)

#911N--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **109.95**(2.49)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25" **$119.95** (2.79)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$99.95**(2.79)

MA 12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$89.95** (2.79)

MA 12mm-Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$69.95** (2.79)

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#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$89.95** (2.79)

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Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.
.965": $24.95 (2.49) **1.25": $29.95** (2.49)

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Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.49)

Tele-Extenders

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender:*(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$26.95** (2.49)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece. **$36.95** (2.49)

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2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (2.49)

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#680--The most popular 2" focuser ever manufactured. Thousands in use. Spring-loaded gearbox; 3" travel. Includes 1.25" and 2" eyepiece-holders. **89.95**(3.48)

#682—Low-profile 2" focuser; body height only 1.75". Spring-loaded gearbox. Travel: 2.5". Includes 1.25" adapter. **99.95** (3.48)

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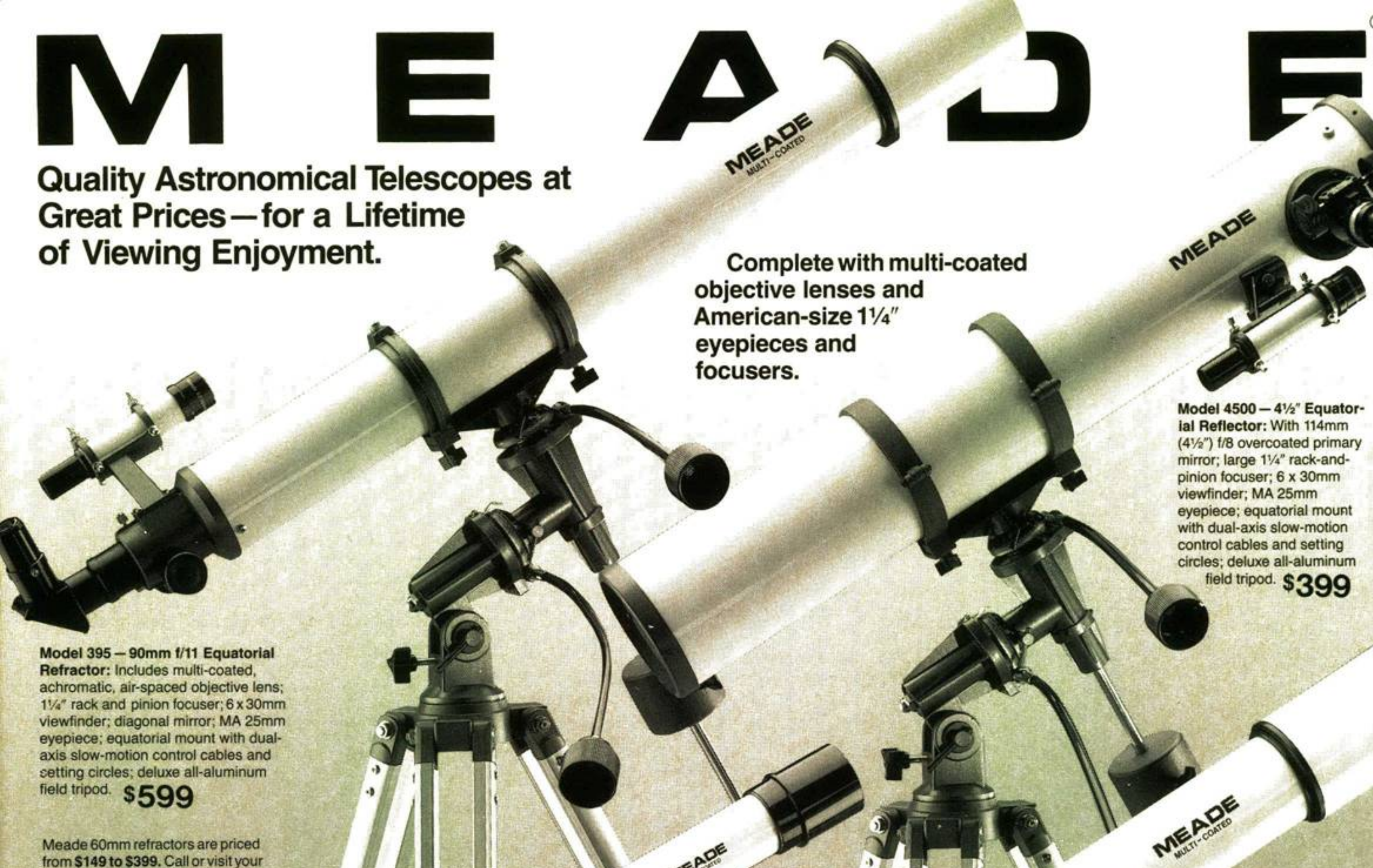

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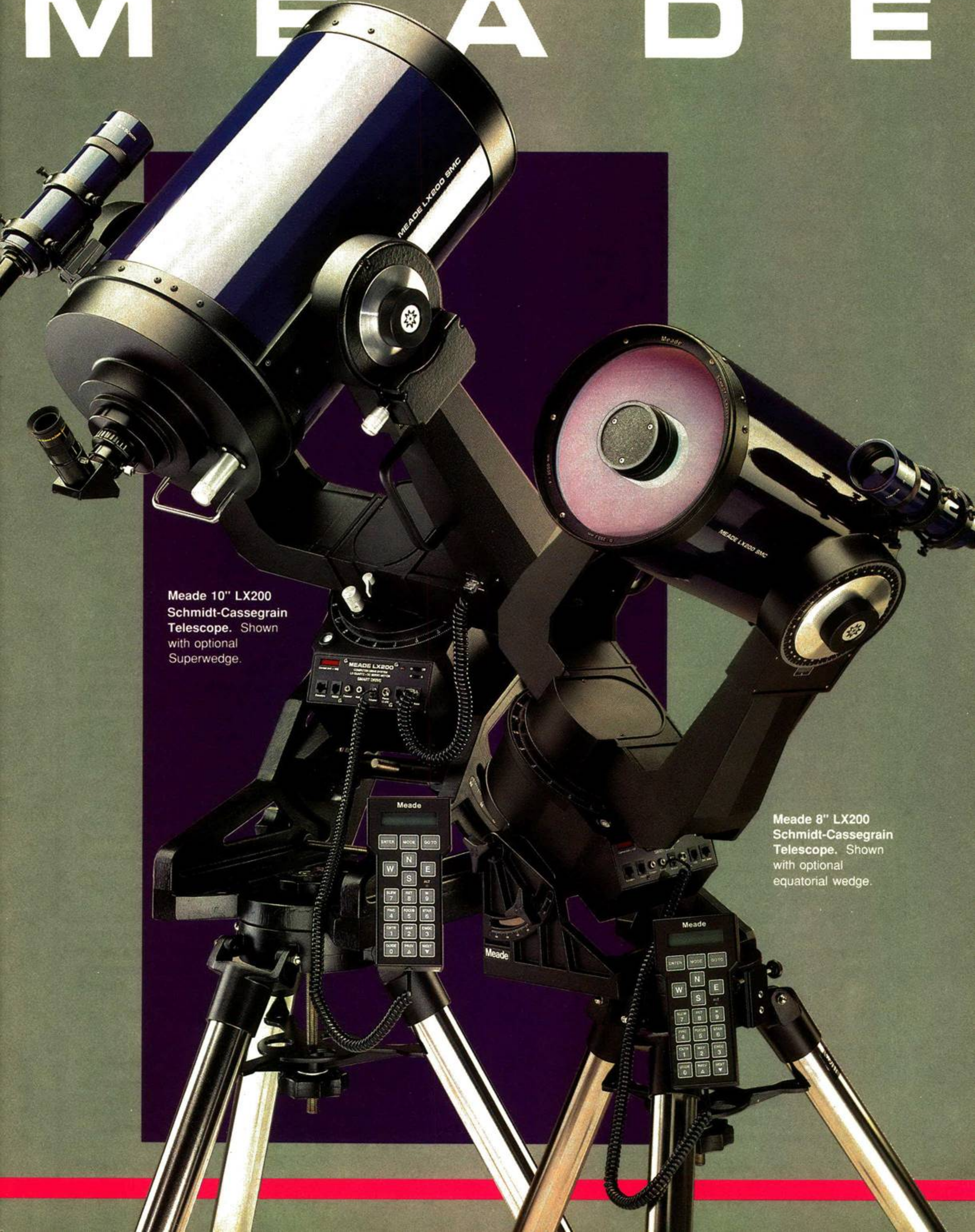
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For me, the best thing was meeting the Rev. Robert Evans, the Australian supernova hunter. He visually takes on automated supernova search telescopes and usually beats them to the punch in discovering faint "guest stars" in galaxies. That was quite refreshing to hear about in these days of ever-increasing automation.

Conferences such as UNIVERSE 92 are important for astronomy. They bridge the gap between seemingly distant groups of people and bring amateur astronomers closer together. That is the single most important factor for the future growth of the hobby. — *Suresh Sreenivasan, Palos Hills, Illinois*

— The 1993 meeting of the Astronomical Society of the Pacific will take place on July 10 and 11 in San Diego, California. For more information, write the ASP, 390 Ashton Avenue, San Francisco, CA 94112.

The Tallness of Storms

I enjoyed Alister Ling's article "Volcanic Twilights" (August 1992). Yet Mr. Ling is mistaken about the height of energetic thunderstorms. In one part of the article he writes, "Low-lying clouds are often 2,500 feet up, wispy cirrus forms near 35,000 feet, and the tallest and most violent thunderstorms tower no higher than 50,000 feet. Volcanoes obviously pack quite a punch to propel material as high as 70,000 feet."

First of all, this last week the National Severe Storms Forecast Center in Kansas City issued several bulletins describing cumulonimbus cloudtops well over 50,000 feet. Second, NASA space shuttles have imaged tropical cumulonimbus tops at 70,000 to 75,000 feet. — *Randall L. Rathbun, TRW Defense Group, San Diego, California*

Who's Got the Best Black Hole?

Readers of Ken Croswell's article "The Best Black Hole in the Galaxy" (March 1992) may have been left with the unfortunate impression that Cygnus X-1 is a low-mass black hole, perhaps less than three solar masses. However, the spectrum and light curve of this binary offer evidence that the black hole is much more massive. Tom Bolton and I argued in a 1986 article (*Astrophysical Journal*, 304:371) that if the visible star rotates synchronously (with the same face always directed toward the black hole) then we can estimate its size (relative to the distance between the star and the black hole) by observing the star's rotational velocity (through Doppler broadening of its spectral lines). The size is important becaus we believe the star is close to filling it Roche surface, the critical size at whic the star begins to transfer mass to th black hole, and the size of the Roch surface in turn depends on the relativ masses of the two components.

Thus we estimate that the blac hole has about one-half the mass of th visible star. The other clue is provide by the light variations that result fro the changing orientation of the tidall distorted visible star as it orbits th black hole. The amplitude of the ligh variation depends critically on the inclination of the orbit to our line o sight, and by comparing calculation for the distorted star with the observe light curve, we find an inclination o 32°. Combined with information on th orbital motion and the mass ratio, w arrive at masses of 33 solar masses fo the visible O star and 16 solar masse for the black hole. Thus the black hol in Cygnus X-1 may well be twice th mass of the one in A0620-00. — *Douglas R. Gies, Georgia State Universit Atlanta, Georgia*

The Trial of Star Hopping

After reading Marcel Bergman's article on star hopping (September 1992) wanted to share some comments wit your readers. After much trial and erro with Bergman's methods, I felt that th concept had merit, but there's an easie way to star hop.

The routes seemed to be using directions like northwest, southeast, and s on which is fine, if you know the directions in the sky. But why not find bright star with approximately the sam right ascension or declination as the object in question and let the telescop drift to the correct position? All that i required is pretty decent polar alignmen of the mount (see "How To Polar Alig Your Telescope," May 1992).

I hope other observers experimen with methods of finding and viewin deep-sky objects. The most importan thing is to avoid getting frustrated, an keep looking up for the sheer thrill of it — *Mark P. Rosenberg, Newbury Par California*

ASTRONOMY welcomes suggestion and additional information about article and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Bo 1612, Waukesha, WI 53187. Letters ma be edited for length or clarity.

OUTBURSTS

by Ronald E. Royer

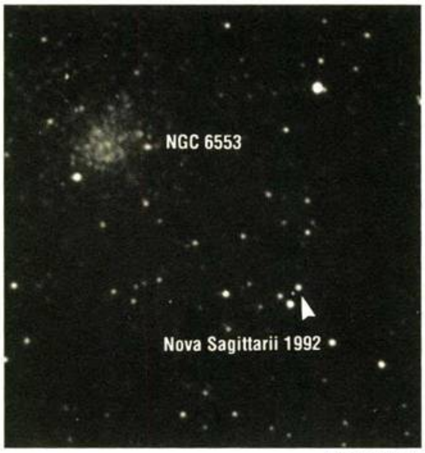
Around the beginning of this year, three stars exploded — Nova Puppis 1991, Nova Cygni 1992, and Nova Sagittarii 1992. Nova Cygni briefly reached naked-eye visibility, but the other two were faint.

Novae are interacting binary star systems in which one star dumps material onto the other until the receiver ejects it in a massive surface explosion. Novae get much attention from astronomers, who in recent years have mounted coordinated studies of them all across the spectrum — from X-ray, extreme ultraviolet, ultraviolet, infrared, to radio wavelengths, as well as the visible.

Professional astronomers can study novae in great detail but are hampered by the fact that they cannot easily maintain watch on this or that object in hopes it will do something. Increasingly, therefore, backyard astronomers are being called upon to keep these fascinating and unpredictable stars under constant surveillance. It's especially important to catch novae before they reach maximum brightness because most of what astronomers wish to know can be learned only in the first days, or even hours, of an outburst.

When a nova erupts, the professionals scramble to redirect their instruments and the American Association of Variable Star Observers (AAVSO) hastens to prepare charts with calibrated magnitudes so that obervers the world over can follow the changing brightness of the star. Nova Sagittarii posed a challenge to chartmakers for several reasons. The region of sky became visible just before dawn, the nova occurred in a rich star field, and it was only 11th magnitude. The AAVSO had no suitable chart on hand and accordingly alerted its network of astrophotographers.

I am a priest at a parish in Lakewood, California, one of the many municipaities in Los Angeles; I'm also an amateur astronomer, AAVSO member, and astrophotographer. Because of the nova's southern declination, the AAVSO asked me to photograph it so they could determine a sequence of calibrated stellar magnitudes for the stars in the nova's vicinity. This past April, after a series of delays, I finally got one photo of the nova. But I needed another picture soon afterward to confirm the identification.



Ronald Royer

The weather being clear, I was setting up on Wednesday afternoon, April 29, for my second photo. The nova would be visible the next morning before dawn. My school-yard observatory lies immediately next to Lakewood Regional Medical Center. Walking by one of their buildings I learned of the verdict in the Rodney King police-brutality trial. I guessed immediately that the night would be full of uncertainty, since racial tensions had been building throughout the trial.

I had planned to be up all night anyway. But after news of the verdict broke, I decided to keep an eye on the property, monitor TV reports, and stay alert to the parish's needs. I also watched the activity at the hospital emergency entrance, and hoped to slip in a few variable star observations, if the opportunity came.

It was scary-quiet as local businesses boarded up. Then a nearby pawnshop was truck-rammed. This act was contained within a few minutes by the L.A. county sheriff's department, but not before about 50 guns disappeared into the tense environment.

As the night wore on I was able to do some observing and took two photos of the nova before dawn. The sky was extremely clear, with a light east wind blowing — a rare thing this late in spring. The wind kept away the smoke from the riot-caused arson. As dawn came on, I joined the hospital people in evaluating the night with relief, when suddenly a large plume of smoke arose from a fast-food place across the street,

[continued on page 16]

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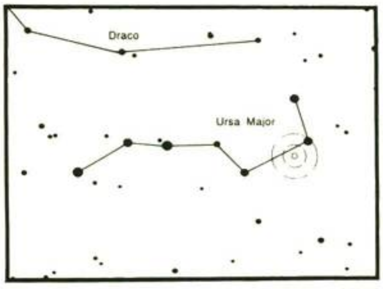

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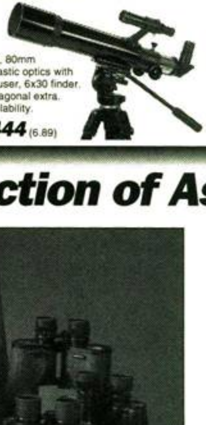
Orion Ultrascan 80



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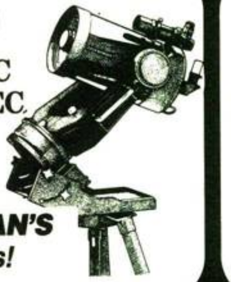

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the work of a solitary, perhaps copy-cat, arsonist.

Such a terror-filled night and the days that followed prompted some thoughts in me. We make great efforts to study the nature of things, such as stars and the rest of the physical universe. Yet so often we overlook the human condition. Perhaps in human affairs we should be using as much talent, dedication, and cooperation as professional and amateur astronomers use in studying the stars together. The heavens we can understand yet not influence, but human beings *can* be influenced to live together better on this very small and fragile planet Earth.

As for novae, astronomers have learned that one star in the pair is continually dumping matter upon its companion, and experience has shown that the imbalance eventually results in an explosion. As citizens, we should be just as sensitive and alert to conditions that can cause human explosions. Riots seldom surprise students of human nature. Animals have instincts to guide them in raising their young, but humans need prolonged upbringing. Lacking this training, which we sometimes call discipline, people can go out of control and explode, inward or outwardly. In an eerie parallel to the stellar world, it seems that human beings cannot be dumped upon by unjust, uncaring systems — or by simple neglect — without an explosion.

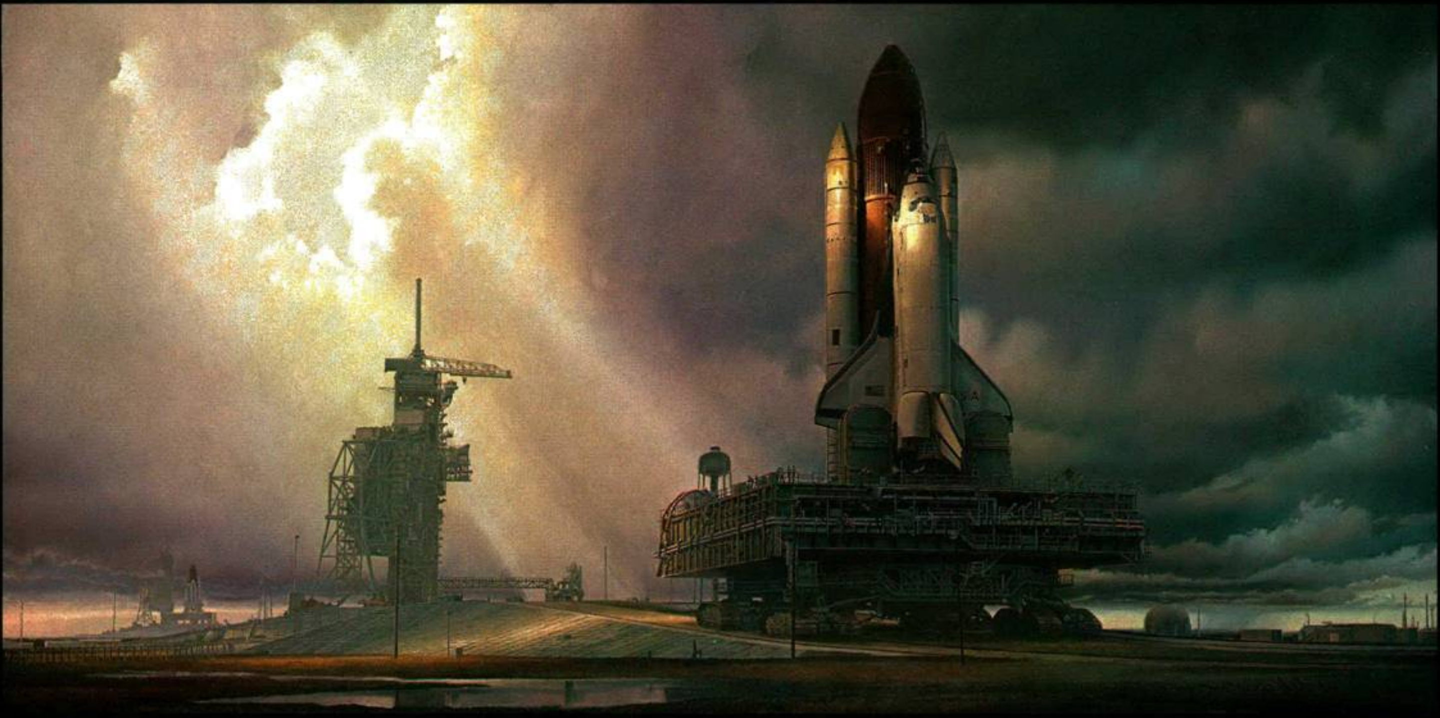
Exploding stars are interesting to watch; in fact, astronomers don't study unchanging stars all that much. But people exploding with emotion are terrifying to experience and so much is lost and wasted. We should be able to do better.

Is the answer to be found in pitching money at social problems? Not if we just rebuild the same structures. Novae recur again and again because the same unbalanced physical arrangement remains. Why should human systems respond differently? Perhaps if we study the less visible factors of social behavior, we can get a handle on these human explosions that are erupting worldwide.

In my view we have to work constantly for justice and personal responsibility. When we grant individual rights, we must also insist on individual responsibilities. The task is big, but if we neglect it we may no longer have opportunities for studying the heavens and another Dark Age could descend upon us all.

"Can't we all get along?" asked Rodney King.

Can't the stars teach us something about human situations? □



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Cape Winds

Attila Hejja

As man's greatest technological achievement, the Space Shuttle stands as a proud monument to American persistence of vision. In this dramatic and visionary painting entitled *Cape Winds*, official NASA artist Attila Hejja commemorates the triumph of the US Space Program. *Cape Winds* is now available to the public for the first time, and Blair Art Studios is pleased to offer signed lithographs of this spectacular work.

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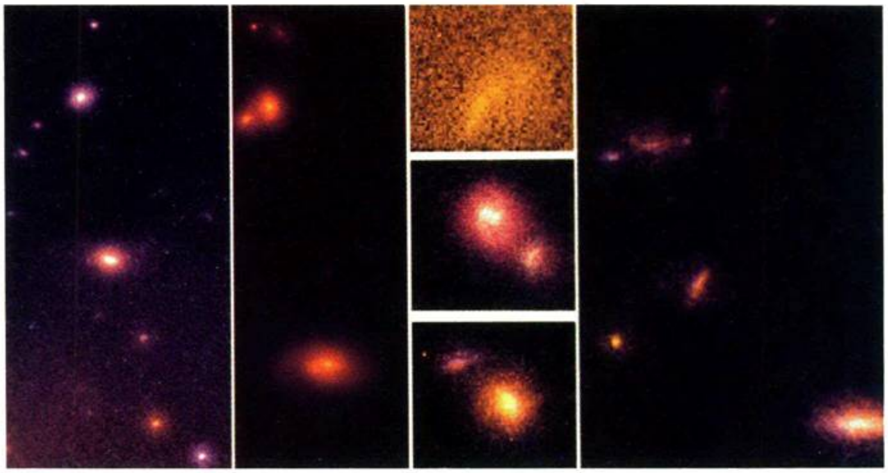
HUBBLE IMAGES EMBRYONIC GALAXIES

A survey of the sky being made with the Hubble Space Telescope has uncovered a host of remote galaxies with unusual shapes and structures. According to Richard Griffiths of the Space Telescope Science Institute, who reported on the new observations in June at the Science with the Hubble Space Telescope workshop in Sardinia, Italy, these tantalizing preliminary results may lead to a better understanding of how galaxies form and evolve.

Some of the observed galaxies, estimated to lie up to 10 billion light-years from Earth, do not have the familiar spiral and elliptical shapes characteristic of most nearby galaxies. One cosmological model holds that galaxies in the early universe interact dynamically and grow larger by cannibalizing smaller galaxies. If this is true, the objects revealed by HST may be the building blocks for today's large galaxies.

The discoveries came as part of HST's Medium-Deep survey, in which the telescope's Wide Field Camera takes pictures of a random field while the primary instrument, such as a spectrograph, observes a different target about 5 arcminutes away. By operating two instruments simultaneously, HST operators can greatly increase the telescope's efficiency. Griffiths expects HST to record several thousand images in several different wavelengths (including ultraviolet, visible, and infrared) during the course of the survey.



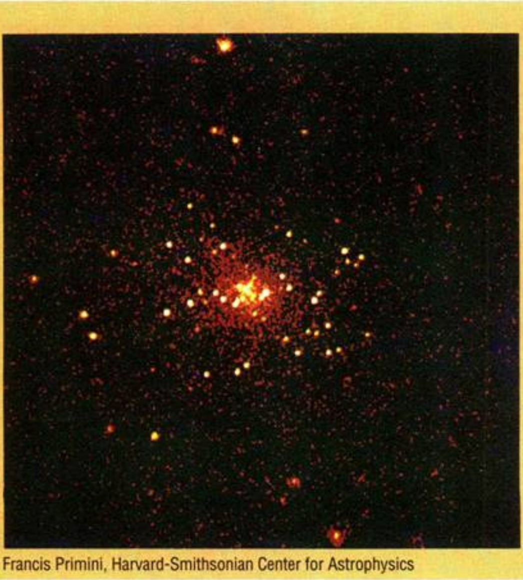
Richard Griffiths (STScI) and NASA.

INTERACTING AND MERGING GALAXIES apparently were common in the early universe, a preliminary conclusion based on images of remote galaxies made during HST's Medium-Deep survey. These images are color composites of visible light images (yellow) and near-infrared images (red).

PLANETS FOUND?

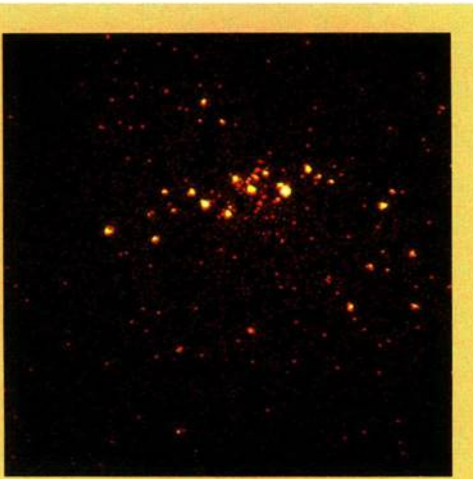
The latest sighting of low-mass companions to stars occurred in a giant gas and dust complex of our Galaxy called the Taurus-Auriga region. Kenneth Marsh and Michael Mahoney of NASA's Jet Propulsion Laboratory used Infrared Astronomical Satellite data to study the disks around young T Tauri stars in this region. Gaps in the circumstellar disks suggest the presence of a body that has swept up or accreted disk material.

They found eight stars with gaps in their circumstellar disk. In all cases but one, the orbiting companion to the T Tauri star can be a planet, a low-mass and faint star, or a brown dwarf. A brown dwarf is an object that forms like a star but has insufficient mass to start the nuclear fires at its center. Additional observations obtained from the ground during an occultation of GK Tauri by Earth's Moon, however, indicate that its companion is too faint to be a star. The



Francis Primini, Harvard-Smithsonian Center for Astrophysics

PROBING THE HEART of the Andromeda Galaxy, ROSAT detected X rays from 18 globular clusters, 2 supernova remnants, and 66 as-yet unidentified point sources (left). Compare this recent view with a 1979 X-ray image taken by the Einstein Observatory (right), and you'll see that many of the sources have changed intensity over the intervening decade.



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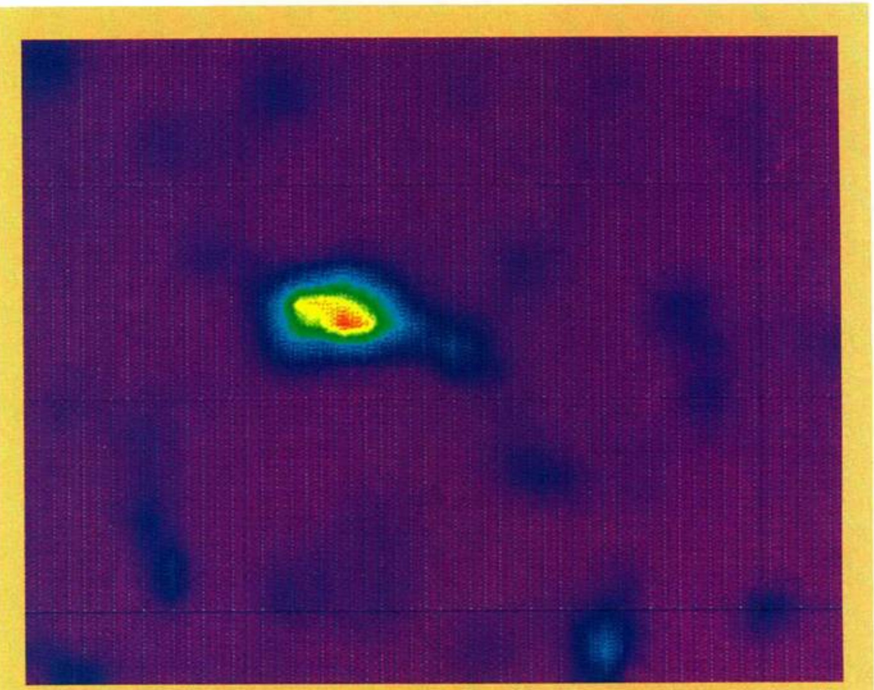
body orbiting this star must be a brown dwarf or one or more planets.

Marsh and Mahoney also found the stars' disk temperatures near the outer edge of the gap averaged around 235 kelvins (K). The condensation temperature for water in a circumstellar disk is about 200 K. The astronomers feel this result is significant and suggest that the formation of a star's first gas giant planet begins in the disk where the temperature is low enough for water to condense.



University of New Hampshire

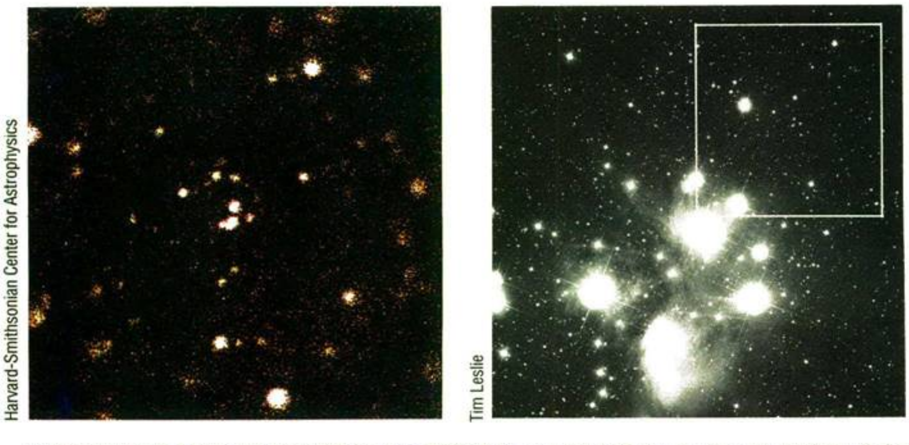
GAMMA RAYS POURED from the Sun during an intense solar flare on June 11, 1991. The flare arose in a magnetic region huge enough to be visible to the naked eye from Earth. The gamma rays were recorded by the COMPTEL instrument on the Compton Gamma Ray Observatory. The gamma rays — produced by cosmic rays energized by the flare — kept coming for more than four hours, over ten times longer than the gamma-ray emission seen in any previous flare. The long lifetime implies that the solar cosmic rays were trapped in the Sun's magnetic field, much as charged particles get trapped in Earth's Van Allen radiation belts.

ROSAT IMAGES OPEN STAR CLUSTERS

Every backyard stargazer knows the Pleiades (M45), the bright open cluster lying in northwestern Taurus. To the naked-eye, the six or seven brightest stars form a distinctive dipper-shaped asterism, while through binoculars dozens more bright stars come into view.

But that familiar view would be turned upside down if our eyes were sensitive to X rays and not optical light. In fact, most open star clusters look completely different in X rays than they do in optical light. Recent observations made with the ROSAT X-ray satellite show that the bright, high-mass stars seen visually disappear, while lower-mass stars dominate.

Normal stars emit X rays through processes associated with their rotations and with the interaction of that rotation with magnetic fields and turbulent motions in their outer atmospheres, or outer convective zones. Because younger stars rotate faster and generally have stronger magnetic fields than older stars, younger stars tend to generate much more X-ray emission than do middle-aged stars like the Sun. By measuring the X-ray flux of stars of varying ages and masses, astronomers can learn about the physical processes taking place in the outer convective zones of these stars and may also get a better picture of what the Sun was like when it was a young star.



Harvard-Smithsonian Center for Astrophysics

Tim Leslie

THE PLEIADES LOOK DIFFERENT in this ROSAT X-ray view of the northwest portion of the star cluster (left) compared to an optical photo of the same region (right, in box). Although the emissions from the cluster's hot stars would normally dominate at all wavelengths, the hot outer atmospheres of the young cool stars strongly emit X rays, dominating the ROSAT image.

Now John Stauffer, Charles Prosser, and Lee Hartmann of the Harvard-Smithsonian Center for Astrophysics and Jean-Pierre Caillault of the University of Georgia have observed the Pleiades with ROSAT. All the stars in this relatively young cluster are the same age, about 60 million years old. Thus by looking at the cluster, astronomers can see how X-ray emission varies with the mass of a star. What they find is that the high-mass stars, which do not have outer convective zones, generally don't show up in the X-ray images. Instead, the brightest stars in X rays have masses around that of the Sun.

Stauffer and Prosser have also joined with other astronomers to examine a number of other open clusters, where they find the same relationship. By comparing the data for clusters of varying ages, they hope to pin down how X-ray emission depends on both the age and mass of a star.

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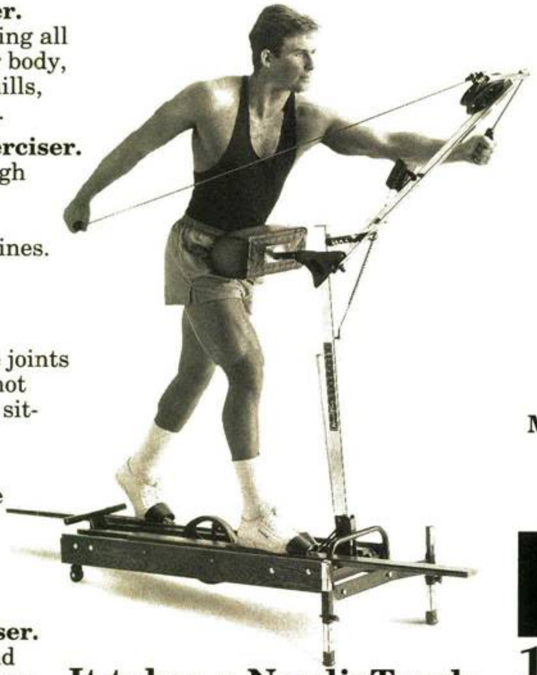

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HST IMAGES DISTANT CEPHEIDS

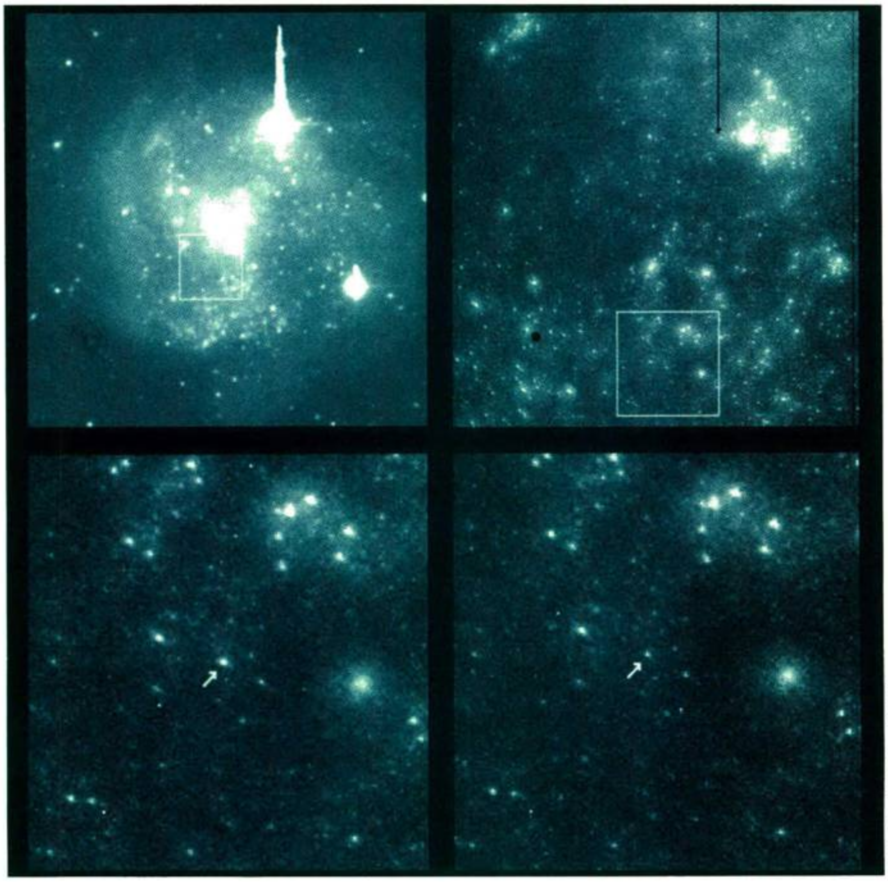
Astronomers observing with the Hubble Space Telescope have located 27 Cepheid variable stars in IC 4182, a faint spiral galaxy that lies 16 million light-years from Earth in the constellation Canes Venatici. These observations will help refine both the distance scale and expansion rate of the universe, two values critical for determining the universe's size and age. A preliminary analysis of the new data shows that the universe may be larger and older than many astronomers previously thought.

Astronomers Allan Sandage of the Observatories of the Carnegie Institution of Washington, Gustav Tammann of the University of Basel, Switzerland, and Duccio Macchetto, Nino Panagia, and Abhijit Saha of the Space Telescope Science Institute announced their findings at Science with the Hubble Space Telescope, an international workshop held in Sardinia, Italy, in June of 1992.

Cepheid variables rhythmically pulsate in brightness with periods measured in days. Early this century, astronomers found that the period of a Cepheid's variability was directly related to the star's intrinsic brightness. By comparing the star's observed brightness with the true brightness, astronomers could easily calculate the star's distance. Fortunately Cepheids are intrinsically bright, making them among the easiest stars to see in external galaxies, so they became highly reliable "standard candles" for estimating intergalactic distances.

The research team chose IC 4182 as a target for their Cepheid search because it was the site of a type Ia supernova explosion observed in 1937. Type Ia supernovae arise in binary star systems in which a white dwarf star accumulates so much mass from its companion that it becomes unstable and detonates in a thermonuclear explosion. Theoretical models predict that all type Ia supernovae should reach approximately the same peak brightness. Thus they also can be used as standard candles, if we know their intrinsic brightnesses.

The problem is that astronomers haven't been able to pin down the absolute brightness of these supernovae at maximum light. By accurately determining the distance to IC 4182 using Cepheids, astronomers can calibrate the intrinsic brightness of the 1937 supernova. And because type Ia supernovae are tens of thousands of times brighter than Cepheids, we can use them to determine large cosmological distances. In effect, the new observations link together two rungs on the cosmological distance ladder.



Abhijit Saha (STScI) and NASA

HST IMAGES CEPHEIDS in the galaxy IC 4182 and thereby helps refine the distance scale of the universe. A ground-based image of the faint spiral taken with the 200-inch Hale telescope (upper left) shows few individual stars, but when HST viewed the small portion of the galaxy shown in the box (appears enlarged at upper right), numerous stars appeared. The two bottom images show an enlargement of the boxed part of the upper right frame, with a Cepheid variable near maximum light (left) and minimum light (right) marked by arrows. These observations imply that the Hubble Constant is only 45 km/sec/Mpc and the universe is at least 15 billion years old.

This is a critical step in refining the value of the Hubble Constant — the rate at which the universe is expanding. Previous estimates for the Hubble Constant varied by a factor of two, from 50 to 100 kilometers per second per megaparsec. (In other words, for every million parsecs farther out you go, the rate of expansion of the universe increases by between 50 and 100 kilometers per second.) Using the absolute brightness of the single supernova in IC 4182, the researchers find a value for the Hubble Constant between 30 and 60 km/sec/Mpc. The most probable value for the Hubble Constant lies in the middle of this range — at 45 km/sec/Mpc — which implies a minimum age for the universe of 15 billion years.

The astronomers plan to narrow this range by observing Cepheid variables in other galaxies that have had recent type Ia supernovae. They will get their chance next year during another HST observing run. And when the second generation Wide Field/Planetary Camera gets installed late next year, the astronomers expect to detect Cepheids out to the Virgo cluster of galaxies, estimated to be 60 million light-years away. Ultimately they hope to use HST to refine the distance scale of the universe to within 10 percent.

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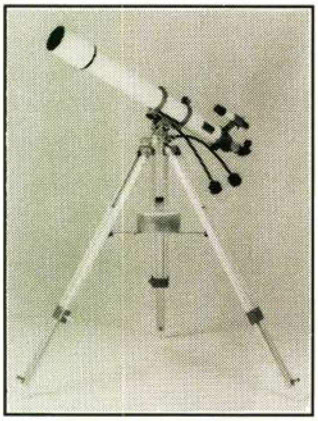

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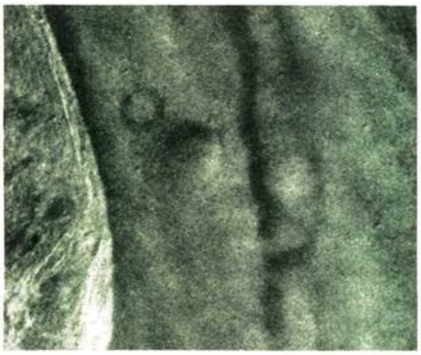
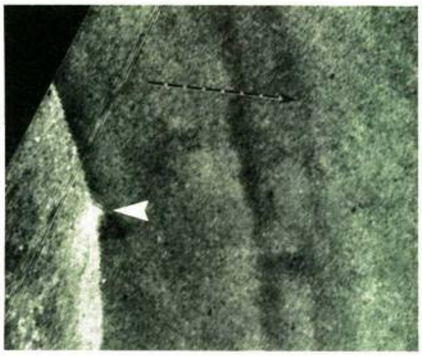
still geologically active. The first photo (top) taken around 1:30 p.m. local Mars time on September 10, 1978, shows an uneventful view of the edge of the plateau Baetis Mensa located in the Valles Marineris region. But the second photo, taken 2 minutes and 23 seconds later, reveals both the sudden appearance of a bright cloud above the plateau's edge and a dark blob — possibly a shadow cast by the cloud. Baerbel K. Lucchitta and Holly M. Ferguson of the U.S. Geological Survey in Flagstaff, Arizona, believe the cloud is composed of dust resulting from a landslide.

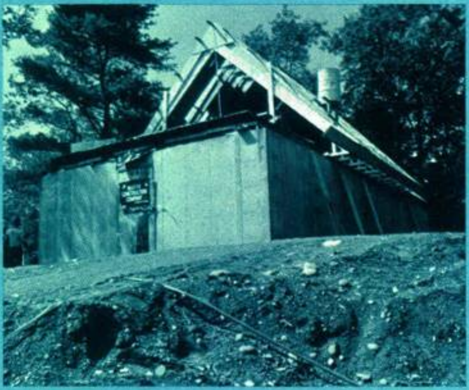




NASA/K.K. Lucchitta and H.M. Ferguson

"It appears too quickly to be a vapor cloud," Lucchitta says. Captured in the second photograph, the cloud is about 3,300 feet long and 1,650 feet wide. It parallels the plateau's edge. The length of the cloud's shadow and the sun-elevation angle of 31 degrees indicate that the cloud was nearly 2,000 feet high when captured by Viking's cameras. (The dashed arrow indicates the direction of the sunlight.) Assuming the cloud rose from the Martian surface, it must have done so with an average speed of over 13 feet per second in the time between the two photos, Lucchitta says. She speculated that the landslide was caused by soil loosened from the warmth of the afternoon sun, indicating that the Martian landscape is still undergoing changes. — *Joseph Baneth Allen*

BIG YEAR FOR STELLAFANE



ASTRONOMY: David J. Eicher

A ROLL-OFF-ROOF STRUCTURE will house the Springfield Telescope Makers' 13-inch Schupmann refractor, giving Breezy Hill and the Stellafane convention a second permanent observatory.

The 57th Stellafane convention in Springfield, Vermont, took place July 31 and August 1, 1992. Many of the more than 1,000 amateur astronomers who attended showed up on Friday, July 31, a day when New England experienced a continuous, steady rain. Despite the inclement weather, however, Stellafaners hobnobbed about Breezy Hill, where the convention has taken place since the 1930s, and enjoyed each other's company immensely.

The traditional Friday night informal "tent talks" offered an array of subjects focused on telescope making. New Yorker John Vogt described his years-long project of grinding and polishing a 32-inch mirror blank that went into the massive Dobsonian scope he brought to the convention. The views it provided on Saturday night, after the rain gave out and the clouds cleared, were outstanding. Alan French of Scotia, New York, highlighted the correct definitions of terms used in telescope making and lamented over their misuse by many in the field. Members of the Amherst Area Amateur Astronomers Association of Massachusetts shared with the audience their plans to construct the Arunah Hill Natural Science Center, an observatory complex for public use in Cunningham, Massachusetts. Plans for the observatory include a 6-inch refractor and 24-inch reflector. John Martin, President of the Springfield Telescope Makers, outlined his group's plans for constructing a 13-inch Schupmann refractor in a permanent, roll-off-roof observatory on Stellafane's lower field, where most of the gathering now takes place.

At the summit of Breezy Hill, around Stellafane's iconic Little Pink Clubhouse and the Porter Turret Telescope, stood an impressive array of amateur telescopes entered into optical and mechanical judging. The optical judging could not take place on Friday night because of rain, but judging on mechanical design and overall craftsmanship occurred on Saturday afternoon. John Mitton of Erin, Ontario, won first prize in the mechanical design category for his 5-inch f/8 refractor; second prize went to Tom Noe of Wylie, Texas, for his 10-inch f/15 collapsible Dobsonian. (This really was a collapsible telescope, having been carried from Texas by Noe on his motorcycle.) First and second prizes in the craftsmanship category went to Mike Jean of Athol, Massachusetts, for his 4-inch folded refractor and John Mitton for his refractor.

Other unusual telescopes graced the hill. Paul Calantropo of Winchester, Massachusetts, brought a massive $12\frac{1}{2}$-inch f/15 refractor with a beautifully machined tube that required a moving van to transport. The lens was ground near the turn of the century by the famous optician Carl Lundin. Warrenton, Virginia's Jerry Wolczanski displayed his well-built observing chair that can be used as a binocular viewing stand. Jim Daly of Ipswich, New Hampshire, showed his $2\frac{1}{4}$-inch Schmidt camera, an instrument that could sit in the palm of the hand in addition to producing dramatic astrophotos.

Saturday's events included Stellafane's famous swap meet and talks on telescopes by Philip Rounseville, David Shafer, and Berton C. Willard. As darkness fell on Saturday and observers could see that clear skies were ahead, a feeling of relief for starlight and dry clothes spread over the audience. Hushed, seated on a hillside in the humid woods, the Stellafaners listened to Walter Scott Houston, deep-sky observer and author, deliver his "shadowgram," reflections on what amateur astronomy is all about. The observers and telescope makers then heard Robert Jastrow, director of the Mount Wilson Institute, detail his plans for reviving the California observatory and creating programs that will make it more accessible to the public. The Stellafaners then did what they do best: walked into the darkness to look up at the stars.

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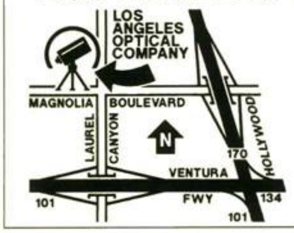

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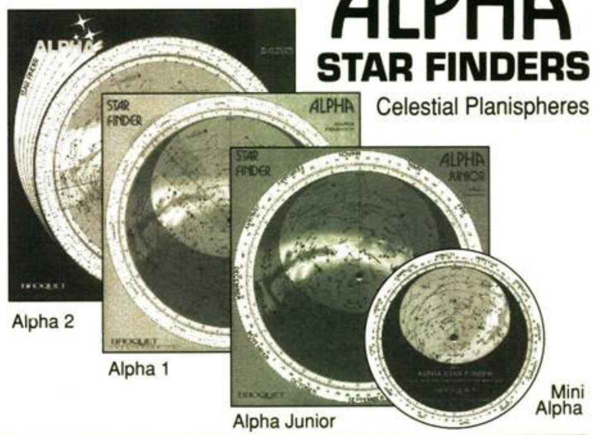

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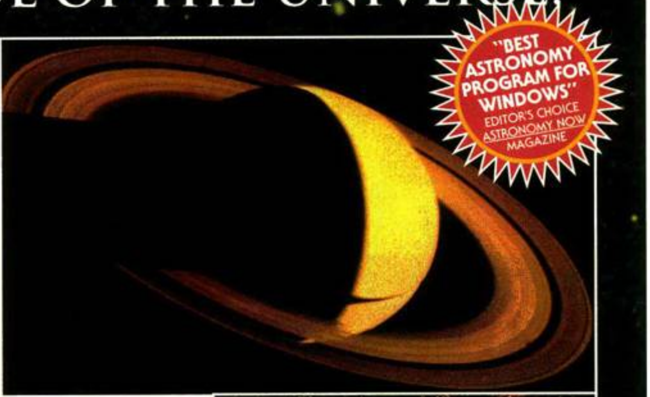
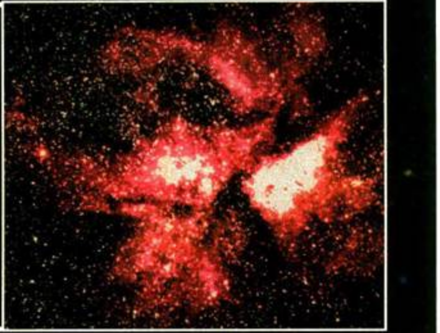


"I'm really boggled – it's beautiful, especially when the lights are off. I'm totally awed by what you have done!"

Arthur C. Clarke,
2001: A Space Odyssey



WHAT POWERS LUMINOUS INFRARED GALAXIES?

Six years ago the Infrared Astronomical Satellite discovered a number of bright infrared galaxies. The galaxy called IRAS 10214+4724 (the numbers refer to the object's position) lies in the constellation Ursa Major. It is the most luminous of these infrared galaxies, pouring out the energy of 100 trillion Suns. Depending on the expansion rate of the universe, it may also be the most luminous object known in the universe.

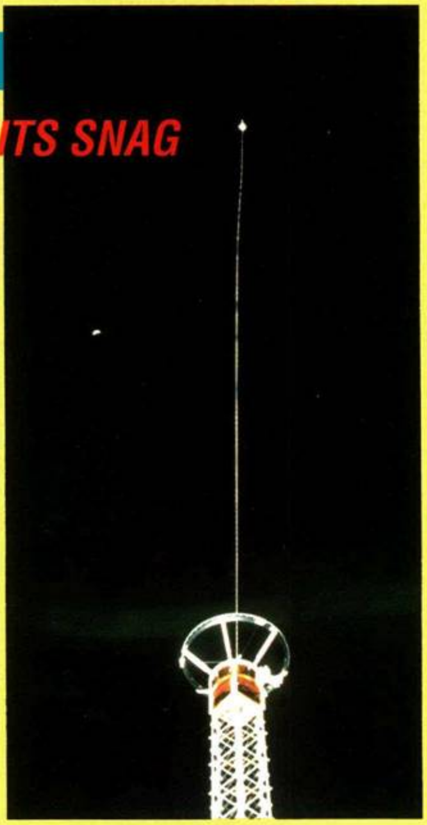
Recent follow-up observations were made with the 30-meter Millimeter Wave Telescope of the Institute de Radio Astronomie Millimetrique (IRAM) near Grenada, Spain, by Philip Solomon of the State University of New York at Stony Brook and Dennis Downes and Simon Radford of IRAM in Grenoble, France. The observations indicate that the galaxy is primeval; that is, 10214+4724 has most of its mass in the form of molecular gas instead of stars. (The galaxy lies at a distance of 10.8 billion light-years, assuming an age of 13.3 billion years for the universe. This distance is too close to us to consider the galaxy to be a protogalaxy, a galaxy that is just forming.) The mass of the galaxy is similar to that of a large spiral galaxy such as the Milky Way Galaxy.

Previously, astronomers thought that black holes must fuel luminous infrared galaxies. But because molecular gas is associated with star-formation regions, the three researchers conclude that a burst of star formation is giving 10214+4724 its unique qualities. "Normally galaxies have a self-regulating mechanism for star formation," says Solomon. "We now know that in infrared luminous galaxies, star-making is a runaway process that is happening at a furious rate."

The astronomers also reported observations made of the dust in the galaxy. Dust is a critical component of 10214+4724 because the young hot stars would otherwise color the galaxy blue. Dust absorbs the bluish stars' radiation and re-emits the energy in the infrared. More importantly, the dust shows that the galaxy's chemical composition is similar to that of our solar system. Our Galaxy took 5 billion years to produce the mixture of chemicals found in the solar system, but 10214+4724's burst of star formation managed to create this mixture in just *2 billion* years. Continued study of this primeval galaxy will teach astronomers more about the early stages of galactic evolution.

Space News

TETHERED SATELLITE HITS SNAG



NASA

THE TETHERED SATELLITE reels out hundreds of feet from the shuttle Atlantis. The Moon appears at upper left.

What promised to be one of the most unusual shuttle flights ever made proved to be only a partial success. In early August, the shuttle Atlantis carried a 1,100-pound satellite into orbit with the intention of reeling it out from the shuttle's payload bay on a 12-mile-long tether. A snag in the cable reel mechanism prevented the satellite from deploying more than 840 feet from the shuttle. Said NASA program manager Thomas Stewart shortly after the mission, "We encountered friction in the system we hadn't counted on. Whether that was due to debris, kinking in the cable, or some other cause is something we now have to determine."

Built as a joint project of NASA and the Italian Space Agency, the Tethered Satellite System was designed to test the applications of tethers in space. In this case the 1/10-inch-thick cable had copper conductors wrapped around the cable's nylon core. When reeled out to its full 12-mile length, the long copper wire moving at 17,000 miles per hour through Earth's magnetic field should have generated 5,000 volts of electricity. As it was, the shortened tether sparked only 40 volts. Nevertheless, according to Stewart, "We demonstrated that tethered satellite systems are feasible. They are stable and can be deployed and retrieved in a controlled manner."

In the future, tethers could be used not only as power sources for satellites but also as rocket motors. Pumping electricity into a tether could impart thrust to the host spacecraft, a technique that might be used on Space Station Freedom as one method of maintaining the station at the intended altitude. Tethers can also be used to launch satellites into higher orbits. For example, a small satellite reeled out 12 miles above the host spacecraft is in a higher orbit but traveling at the greater velocity of its lower-orbit host. If the small satellite is then released, its greater speed (compared to other objects orbiting at its altitude) will fling it into an even higher orbit. The boost in altitude works out to about seven times the length of the tether. A 12-mile tether can send a satellite 84 miles higher than the orbit it started from.

Going the other way, lowering a satellite on a high-tech rope is also an ideal way to troll scientific instruments through the upper atmosphere, layers too high to reach with balloons but too low for free-flying satellites. In the future, engineers might also use tethers to drag aerodynamic shapes through the atmosphere for what amounts to a 17,000-mile-per-hour wind-tunnel test.

Despite the snag, mission planners are hoping for another opportunity to test the Tethered Satellite. According to Stewart, "Everybody involved wants to refly it. We have to find what went wrong and then see if we can get another slot in the manifest."

The August mission also released into orbit EURECA-1, the European Retrievable Carrier built by the European Space Agency. This free-flying platform will remain in orbit until at least June 1993, after which it will be picked up and returned to Earth by another shuttle flight. EURECA carries experiments for growing crystals and for testing the exposure of seeds and eggs to radiation. It also contains an experiment called SOVA (for Solar Constant and Variability Instrument) and SOSP (Solar Spectrum Instrument) that will measure variations in the Sun's energy output over the next few months. A Danish-built detector called WATCH, the Wide-Angle Telescope, will scan the skies for cosmic sources of gamma rays and X rays that burst forth over mere seconds, briefly outshining all other X-ray and gamma-ray sources. ☐

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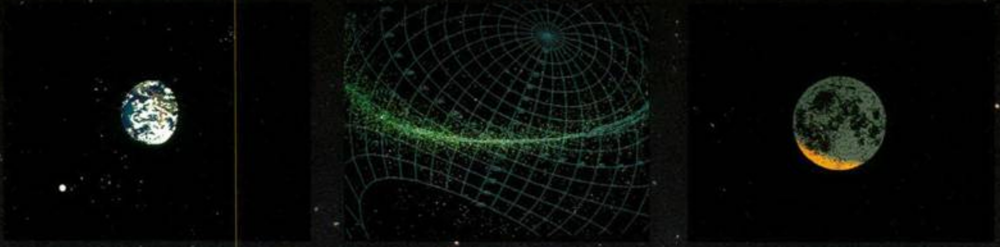

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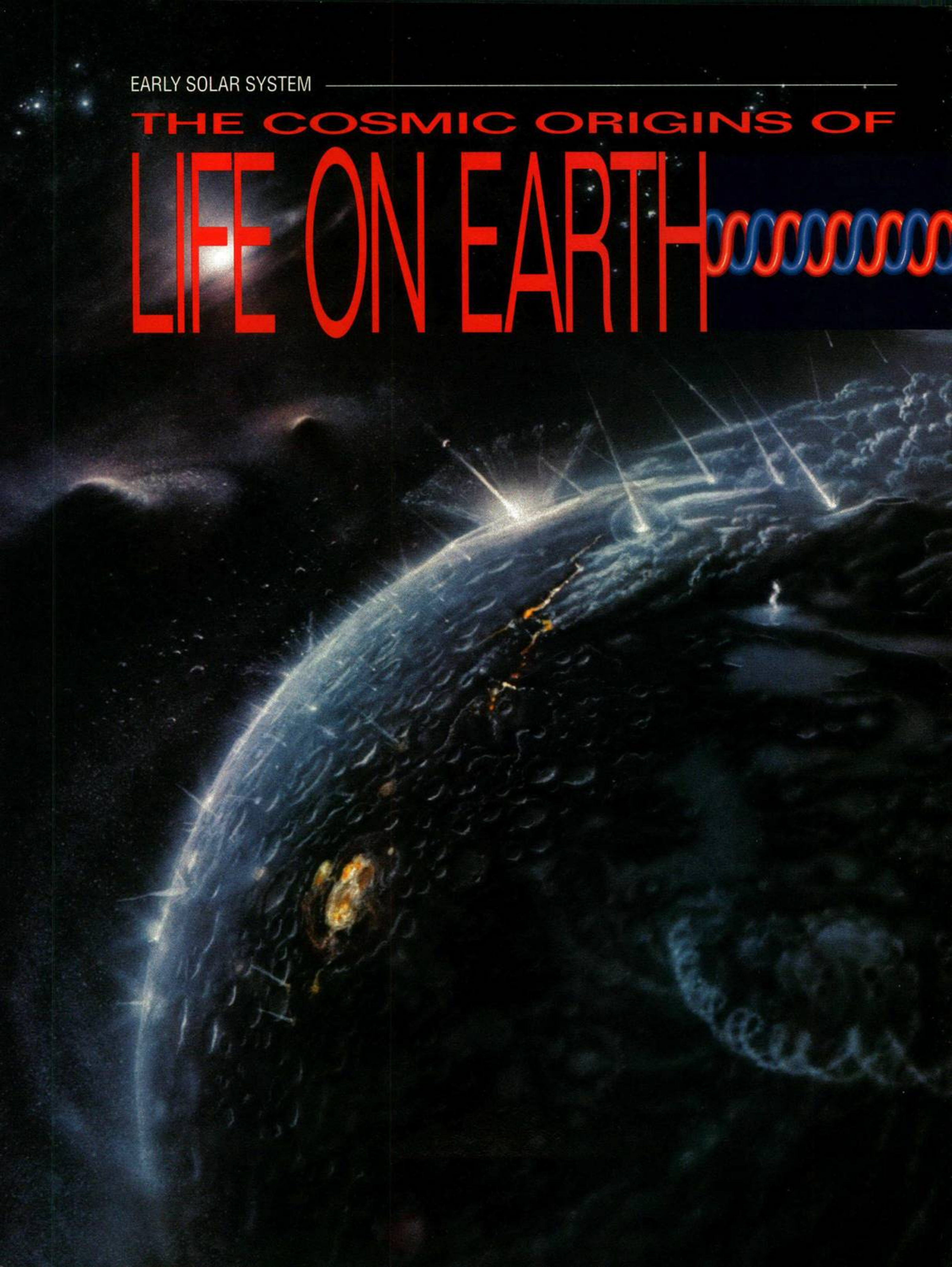
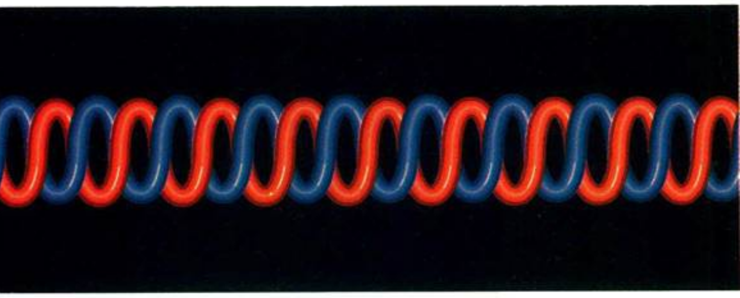


Adolf Schaller

by Christopher Chyba

The essentials of life may have arrived from space billions of years ago and set the stage for life on early Earth. Because of the hostile environment, life may have had to start many times before winning a foothold.

SOLAR SYSTEM BODIES like Comet Halley (left) and the Murchison meteorite (below) contain organic molecules, the stuff from which life is constructed. The Murchison meteorite, found in Australia, is rich in simple amino acids, the building blocks of proteins.



Bobby Bus/Palomar Observatory

J. William Schopf/UCLA

Picture a Full Moon in the night sky. Its bright areas are mountainous highlands; its dark areas are comparatively smooth lowland plains called maria, Latin for seas.

If you gaze at the maria for just a little while, you can quickly convince yourself that many of them are circular in shape. Surprisingly, the reason they are circular is wrapped up with one of our deepest mysteries: the origin of life on Earth. The standard textbook story of how life arose is that simple organic molecules in the oceans of early Earth combined, slowly, to form molecules of greater and greater complexity. These eventually formed a molecule that could copy itself, and the evolution of life was off and running.

However, recently scientists have taken a serious look at an alternative hypothesis for the formation of life — that organic molecules were carried to Earth from extraterrestrial sources such as asteroids, meteorites, comets, and interplanetary dust particles, and that the origin of life got a boost from these cosmic sources. Moreover, it seems likely that life may have started more than once — perhaps numerous times — and because of the hostile conditions on early Earth, repeatedly died out, only to start up again. To examine the credibility of these ideas, let's look at the conditions that existed on early Earth and in the adolescence of the solar system as a whole. This requires a bit of a detour from organic molecules bonding into self-replicating systems. Instead, we must learn about the impact cratering record of Earth and the Moon. It's an unusual place to start in what becomes a very unusual journey of discovery.

Raining Rocks on the Moon

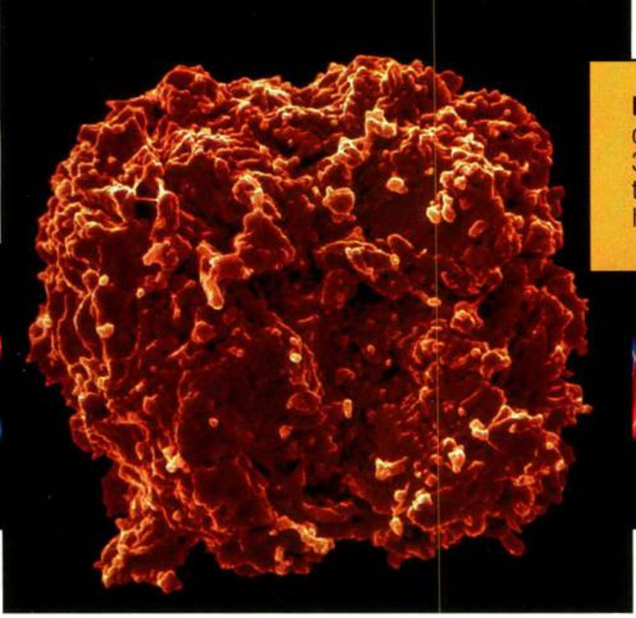
Many of the lunar maria are circular because they got their start as impact basins — essentially giant craters left when asteroid-sized objects struck. (The largest basin on the nearside, Imbrium, is nearly 1,200 kilometers in diameter.) Later, after the basins formed, dark lava flows seeped in and filled them. The lava naturally sought the lowest terrain, but the impacts themselves may have played a key role by excavating far enough into the Moon to give lunar magma a route to the surface. The resulting maria are dark for the same reason that lava flows on Earth are dark once they cool — volcanic basalts reflect little light.

The rocks returned from the Moon by the American Apollo and Soviet Luna missions allowed scientists to build a picture of the lunar surface, and to determine when the critical events occurred. Consider, for example, the Apollo 12 landing site in Oceanus Procellarum, the Sea of Storms. The astronauts made a number of traverses of the area, collecting a variety of samples. These samples came back to Earth, where scientists determined their ages using radioactive dating techniques.

All told, the Apollo missions returned a total of 380 kilograms — 840 pounds — of rocks. Most of the rocks from a particular mission have ages that cluster around the same value — for Apollo 12, about 3.2 billion years old. This means that the particular ancient lava flow on which the Apollo 12 astronauts landed solidified at this time in the past.

Knowing the age of this particular flow, scientists can go to pictures taken from orbit and count how many craters it has. Geologists can be certain that all these craters were produced after that flow solidified, because any craters formed prior to that time were "wiped clean" from the lunar surface, buried by the flowing lava.

Obviously planetary scientists can't count craters of all sizes. For craters that are too small, researchers can't



INTERPLANETARY DUST PARTICLES contain about 10 percent organic molecules and fall slowly to Earth, contributing 300 tons of organics per year. Although each spans less than a tenth of a millimeter, in Earth's early history they may have been a key source of organic molecules.

John Bradley/MVA Associates and Don Brownlee/University of Washington

discern them clearly, even from as close as lunar orbit. In practice, lunar crater counters usually try to pick out only craters bigger than 4 kilometers in diameter. The data from all of the Apollo and Luna missions (see the diagram on page 33) show that prior to about 3.5 billion years ago, the level of cratering was much higher than today. But since then, cratering has been roughly constant at a comparatively low level. The intense cratering prior to 3.5 billion years ago is often referred to as "the heavy bombardment."

The heavy bombardment is consistent with astronomers' current models of solar system formation, which say that as the planets grew in size, they either slowly swept up or gravitationally scattered asteroid and comet-sized bodies called planetesimals. Some planetesimals spun into rogue orbits deep in the inner solar system, and some eventually collided with one of the inner planets. As the planets grew bigger and bigger, more and more planetesimals were swept up or scattered away, and the supply of planetesimals declined. Finally, by 3.5 billion years ago only a very small number of comets and asteroids were left orbiting through the inner solar system and the impact rate dropped sharply as the population thinned.

Lessons from Mercury and Mars

Can we be confident that this is the right story? How sure are we that the objects that excavated the basins and craters on the Moon didn't hit just the Moon and miss Earth altogether? In fact, the Moon probably started its life only a few terrestrial radii away from Earth, evolving outward to its current distance of 60 Earth radii. We might worry, for example, that as the Moon moved out and away from the Earth, it swept up a swarm of debris that dug out the lunar craters. If this were the case, cratering on the Moon would tell us nothing about cratering on Earth. However, spacecraft missions to Mercury and Mars have helped resolve this issue. Start with the oldest parts of the Moon, and imagine counting up the number of craters of different diameters. On the Moon, you find that when you go down a factor of ten in crater size, the craters become more common by about a factor of a hundred. Of course this rule isn't perfect, and some crater sizes are present in greater or lesser number than this simple rule leads you to expect.

Now play the same game with craters on the ancient terrain of Mars, or on Mercury, and what do you find? Not only do you find the same overall relationship between crater number and crater size, but those particular sizes that broke the rule on the Moon break the rule to about the same extent on Mars and Mercury as well. A common interpretation of this similarity in cratering records is that all these worlds were cratered by the same population of objects, a population that had a certain overall size distribution with certain particular sizes over- or underrepresented. But if Mars, Mercury, and the Moon were all pummeled by the same population of impacting objects during the heavy bombardment, Earth and Venus must have been as well.

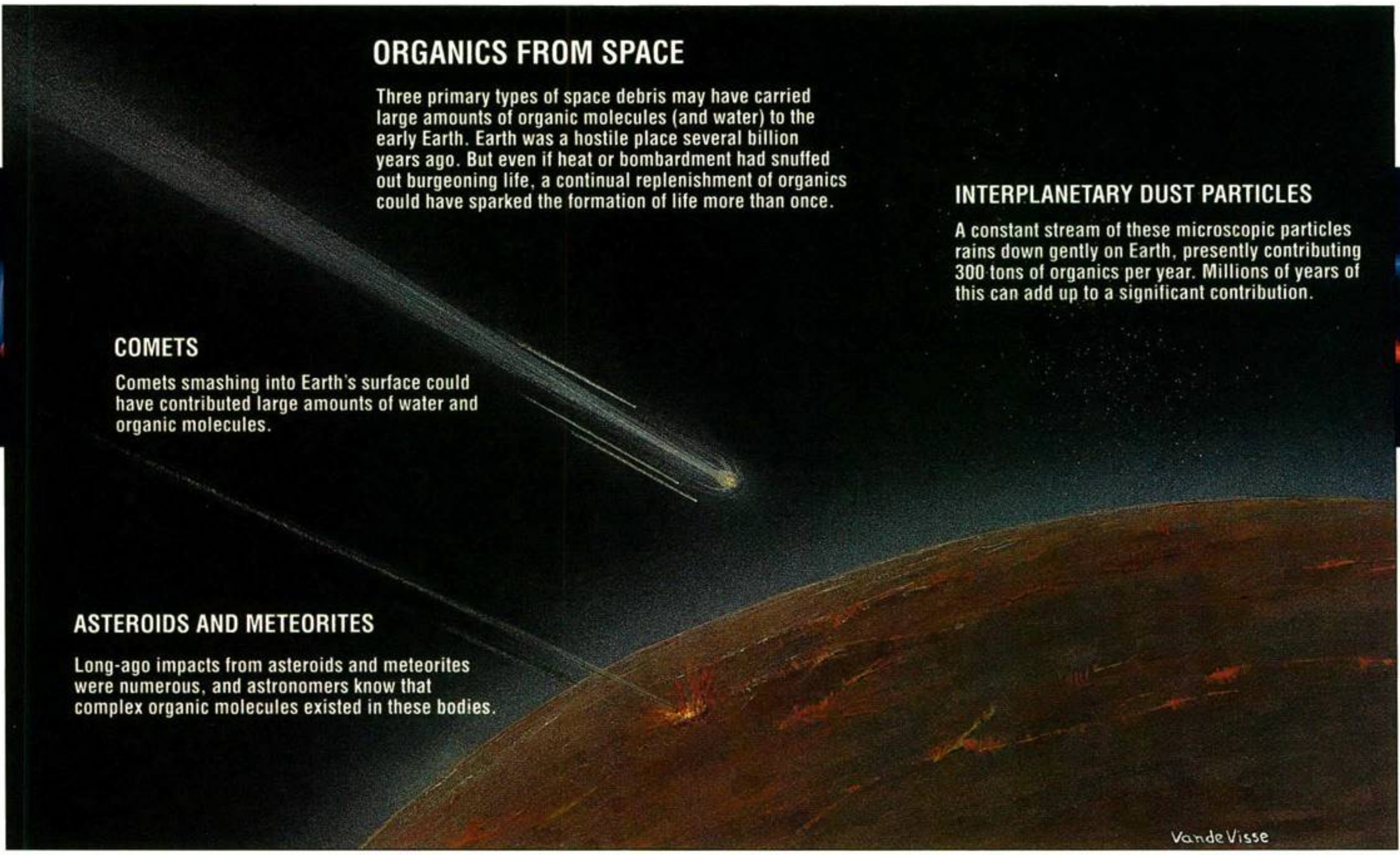
The problem with Earth (and Venus) is that it is so geologically active that it no longer has any of its most ancient crust left intact. We know from radioisotope dating on certain meteorites that Earth is about 4.5 billion years old. Nevertheless, almost no surfaces remain on Earth that date from before 3.5 billion years ago. Not enough ancient surface is left to have preserved a record of the heavy bombardment. On Earth, and Venus, that information has been erased. But it has been retained on at least parts of the surfaces of the Moon, Mercury, and Mars.

Thus, if we want information about the environment of the early Earth, there is no way to get it from terrestrial geology. We simply have to look to the Moon and planets, and try to extrapolate from them back to our own world. To learn about Earth, we must look beyond it. This is true not just in some metaphorical sense, but is quite literally true.

Enter Life

We face the same dilemma when trying to unravel the development of early life. The oldest rocks on Earth capable of having fossils in them have fossils. These include microscopic fossils of bacteria, and the fossilized remains of macroscopic structures, called stromatolites, formed by mats of algae. The sedimentary rocks containing these remains are found in Western Australia and South Africa and are 3.5 billion years old. There are older rocks (3.8 billion years) in Greenland, called the Isua formation. The Isua rocks began as sediments, but over their long life they have several times experienced high temperatures and pressures, making it unlikely that any fossils could have survived within them. Still, controversial claims have been made for signs of life in the Isua rocks as well. The problem is that the Isua formation has been so reworked that it is difficult for scientists to know what they are seeing. Finally, newly discovered granitic rocks found in Canada's Northwest Territories are about 4.0 billion years old. But these rocks formed within Earth at high temperatures and pressures, and so are incapable of containing any fossils.

Thus no record exists of the origin of life on Earth. The oldest geological record already contains fossils



ORGANICS FROM SPACE

Three primary types of space debris may have carried large amounts of organic molecules (and water) to the early Earth. Earth was a hostile place several billion years ago. But even if heat or bombardment had snuffed out burgeoning life, a continual replenishment of organics could have sparked the formation of life more than once.

INTERPLANETARY DUST PARTICLES

A constant stream of these microscopic particles rains down gently on Earth, presently contributing 300 tons of organics per year. Millions of years of this can add up to a significant contribution.

COMETS

Comets smashing into Earth's surface could have contributed large amounts of water and organic molecules.

ASTEROIDS AND METEORITES

Long-ago impacts from asteroids and meteorites were numerous, and astronomers know that complex organic molecules existed in these bodies.

ASTRONOMY: Lee Vande Visse

of sophisticated, probably photosynthesizing microorganisms. So scientists can't get much information about the terrestrial environment before or during the time of the origin of life by looking at Earth. Yet we know from the Moon that this environment must have been an extremely violent, impact-ridden one. The earliest terrestrial fossils coincide in time with the last stages of the heavy bombardment that we have dated from the lunar samples. It seems unlikely that this similarity of dates is just a coincidence. Rather, the heavy bombardment probably played important roles — both positive and negative — in the timing and origin of life on Earth.

But as with any area of research where the data are limited, some scientists contest this conclusion. A minority of lunar scientists argue that the lunar bombardment history presented here is badly mistaken. These scientists note that lunar rocks seem to contain no melted remnants from impacts older than about 3.9 billion years — yet samples of much older lunar lavas and ancient crust have been found. They suggest this means that the Moon experienced only a light bombardment during its first 600 million years, followed by an intense cataclysmic bombardment that produced virtually all of the familiar lunar features.

These conclusions have in turn been disputed. First, the cause of such a "cataclysm" remains a mystery. Second, the lack of ancient impact melts may simply be because, prior to 3.9 billion years ago, the bombardment was so intense that ancient melts were being remelted, and their earlier formation dates were obliterated. But even if the "cataclysm" hypothesis is correct, the question remains: were there important connections between early impacts and the origins of life?

Janus

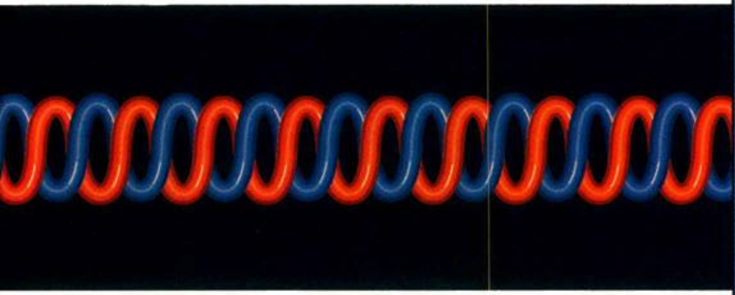
Janus was the Roman god known as the doorkeeper of heaven. Since every door looks two ways, Janus had two faces. As a solar deity, he had one face for the rising, and one for the setting, Sun. It was natural, then, for Janus to be the patron of beginnings, and the patron of ends.

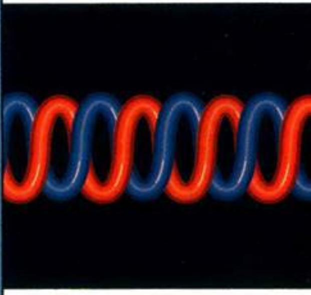
The heavy bombardment on early Earth had this Janus-like quality. It may have repeatedly exterminated life, but it may also have been essential for the origin of life. However, let's first turn to the destructive side of the heavy bombardment, the face of Janus for the setting Sun.

Basin-making impacts on early Earth would have blown some of the atmosphere off into space. Because a thick atmosphere is essential for keeping a planet warm, such "impact erosion" of an atmosphere could have converted an initially hospitable planet into a freeze-dried desert. In fact, many planetary scientists now think this might be exactly what happened to Mars, which once had flowing water on its surface, but now seems to be a nearly airless, dead world.

Apparently Earth's larger size saved it from the same fate. Earth's larger gravity (over $2\frac{1}{2}$ times stronger) makes it correspondingly harder to blast portions of its atmosphere off into space. Detailed studies show that on Earth, asteroids and comets delivered more atmospheric gases than they blew away into space. On Mars, the opposite was probably the case. In the case of the Moon, gravity is so low that impacts would slowly erode not the Moon's atmosphere (which is virtually nonexistent), but the Moon itself. The Moon is slowly being blasted away into the cold confines of space.

Especially big impacts on early Earth had a far more serious effect than just blowing gases into space — including gases helpful to the origin of life. Any one of the largest impacts would have produced a shortlived global atmosphere composed of rock vapor, temporarily raising the temperature of Earth's surface to above that of the inside of an oven. In the most extreme cases, this searing heat would have lasted long enough to have evaporated the entire terrestrial ocean, sterilizing the surface of Earth.





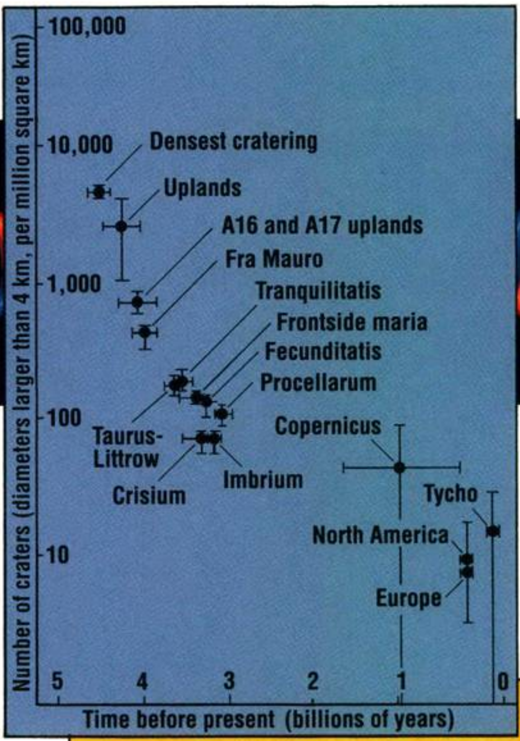
Scientists can use the cratering record on the Moon to estimate just how often this level of destruction took place. Statistically, because of Earth's larger gravity, something like 17 or so objects larger than the largest object that hit the Moon should have collided with Earth. If the largest object that impacted the Moon was the one responsible for the 2,500-km-diameter South Pole-Aitken basin on the lunar farside (whose controversial existence was finally confirmed two years ago by the Galileo spacecraft), Earth was probably hit about five times by asteroids or comets big enough to have completely vaporized its oceans. Another way of saying this is that Earth's surface should have been completely sterilized some five times or so.

If this is right, then life on Earth did not have a billion or so years to get started, the time between Earth's formation and the first recorded fossil life. Life may have had only a tenth of this time. And if life got started this quickly, it probably means that the origin of life was a very easy process.

The dilemma, of course, is with the estimate "five times or so" for the number of times that giant impacts might have heat-sterilized Earth. It could be that Earth's surface was sterilized not 5, but 10 times, and it's not out of the question that it never happened at all. Scientists can't resolve this issue with certainty because there's no record left on Earth. All they can do is statistically extrapolate from the Moon. This puts them in the frustrating position of having to admit that the most calamitous events in Earth's history (after the giant primordial impact that many planetary scientists now suspect was responsible for forming the Moon) can be spoken of only in terms of probabilities, in terms of might-have-been's, or probably-were's.

In any case, even if Earth's surface was never entirely sterilized, many smaller but still giant impacts would have wiped out this or that "warm pond" where promising evolutionary experiments in the origin of life were underway. Somehow life emerged successfully in the midst of all this impact violence.

One way around this dilemma is for life to have evolved not at Earth's surface but at comparatively protected locations deep in the oceans or underground. If life could have evolved, say, at deep-sea hydrothermal vents, its earliest evolution would have been protected against all but the most devastating impacts. But vehement disagreements have raged among origins-of-life scientists over whether hydrothermal vents are in fact suitable locations for the sorts of reactions thought necessary to get life started.



ASTRONOMY: Lee Vande Visse

CRATERING IN THE EARTH-MOON SYSTEM declined dramatically in the first billion years of solar system history, as shown by this plot of the number of craters on different lunar and terrestrial terrains versus the ages of those terrains. Error bars depict uncertainties in crater counts and radioactive dating the different terrains.

Another possibility is that life evolved at Earth's surface but quickly expanded to deep ocean or underground environments. Surface life could then have been obliterated by impacts, leaving only the subsurface communities of microorganisms intact. Life on Earth today would then be the descendants of an early subsurface ecology, simply because these were the only organisms that made it through the heavy bombardment.

The Rising Sun

But Janus had two faces, contemplating not only the sunset but also the sunrise. And at the same time that comets and asteroids were wreaking devastation upon the surface of Earth, they may also have been setting the stage for the genesis of life.

Comets and some asteroids are rich in exactly those elements needed for the origin of life. For example, comets are about 50 percent water ice by mass. If ten percent of the objects that collided with Earth were comets, all our planet's oceans can be explained. Because liquid water is essential to life as we know it, it could well be that comets and water-rich asteroids thereby "fertilized" Earth's surface, rendering it hospitable for the origin of life. And just as important, it appears that much of the terrestrial inventory of biologically critical elements, such as carbon and nitrogen, may have also been delivered in this way.

NASA

J. William Schopf/UCLA

APOLLO 12 ASTRONAUTS failed to detect life on the barren surface of the Moon. Yet the lunar cratering record allows astronomers to reconstruct the period of heavy bombardment and what it must have done to Earth. The oldest known microfossil (above) is 3.4 to 3.5 billion years old, dating back to about the time of the heavy bombardment.

Moreover, comets and some asteroids are rich in organic molecules — those molecules out of which all life-as-we-know-it is made. It's possible that the organic building blocks of life on Earth were initially brought to Earth from outside. In fact, these processes continue to some extent today. Some meteorites, such as the Murchison meteorite (so called because it fell near Murchison, Australia), contain various interesting organics. For example, Murchison is rich in amino acids, the building blocks of proteins. Far more extraterrestrial organics, however, are falling to Earth in the form of interplanetary dust particles (IDPs). These particles, smaller than a tenth of a millimeter across, are small enough to decelerate completely high in the atmosphere before they are heated sufficiently to burn up. They settle slowly and gently down to Earth's surface. As a consequence, their organics — IDPs appear to be about 10 percent organic by mass — survive delivery to the surface of Earth.

Earth is currently collecting some 300 tons a year of extraterrestrial organics delivered in IDPs. Although individual meteorites are vastly larger than any IDP, falls of organic-rich meteorites are so rare that meteorites are now providing Earth with less than 10 kilograms of organic matter a year — less than one ten-thousandth as much as IDPs provide. Nevertheless, comparatively big falls like Murchison are essential, because they provide cosmochemists with chunks big enough to work with.

There are, of course, more dramatic ways to bring organics down to Earth. Over 130 craters are now recognized on Earth's surface, nearly all representing impacts by comets and asteroids over the past few hundred million years. (Most older craters have long since eroded away or been filled in.) Although big impacts with Earth are, fortunately for us, quite rare, far more mass arrives on Earth in these intermittent events than in the slow, steady accumulation of IDPs. If some of these big impactors were organic-rich comets or asteroids, Earth could potentially accumulate vast quantities of organics from this source.

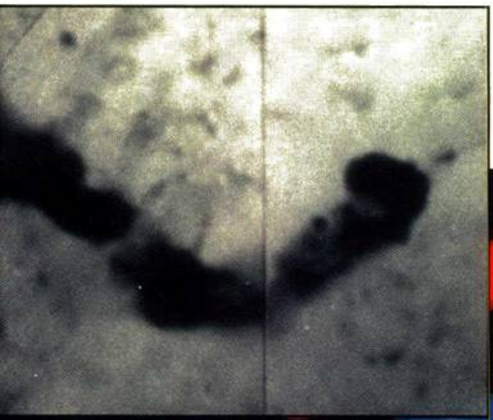
But despite its importance at first glance, this mechanism seems not to work. It is easy to see why: collisions of big asteroids or comets with Earth are extremely violent events. If a body the size of Halley's Comet hits Earth, the resulting explosion has the energy of 100 million tons of TNT. It is difficult to see how organics could survive this kind of holocaust. Detailed computer simulations of the destruction of organics in small comets show that only small comets (hundreds of meters across, say) might have successfully delivered organics to early Earth, because only these bodies are small enough to be slowed sufficiently by the atmosphere for their organics to survive the collision. It's likely that the amount of organics collected by Earth in this way was outweighed by those brought in by IDPs.

Extraterrestrial vs. Terrestrial Sources of Organics

How important were the organics brought in from out there for the origin of life down here? Because scientists don't really understand the origin of life, this question can't be answered with confidence. One way to approach the issue, though, is to compare the extraterrestrial sources with likely sources of organics made on Earth. Since the early 1950s, scientists have worked out a number of ways for making organics via chemical reactions in Earth's atmosphere. How do these stack up against the fine rain of organic-rich dust from the sky?

The answer to this question is complex, because the production of organics on early Earth depends on the details of Earth's primitive atmosphere. Once again, scientists are hindered by a lack of data. About forty years ago, when the first key experiments on organic production in early terrestrial atmospheres were performed, scientists thought Earth's earliest atmosphere consisted of methane and ammonia. In this kind of atmosphere, organics are produced copiously from lightning, ultraviolet light, and other sources. Organic production from these sources is then so efficient that any direct importation of extraterrestrial organics is completely swamped by terrestrial sources.

However, even in this case the heavy bombardment



played an important role. In the early 1970s researchers demonstrated that shock waves in methane- and ammonia-rich atmospheres also produce organic molecules with high efficiency. By using the lunar cratering record to estimate how many impactors of what sizes hurtled down through the atmosphere of early Earth, astronomers can calculate organic production from the resulting shock waves. Doing this, they have discovered that organic synthesis from these shock waves is as important as any of the other sources, such as lightning or ultraviolet light.

But most geochemists no longer think that Earth's early atmosphere consisted of methane and ammonia. The composition of the atmosphere of early Earth was governed by the chemistry of Earth's mantle and crust, and the clues we have about this chemistry now point toward an early atmosphere rich in carbon dioxide and molecular nitrogen, not methane and ammonia. In this case, laboratory experiments have shown that it is vastly more difficult to synthesize organics in Earth's atmosphere. So it is exactly in this case where the extraterrestrial sources loom in importance. In this less hospitable kind of atmosphere, IDPs could have been the dominant source of organics on early Earth.

The debate about the composition of Earth's early atmosphere is far from settled. Remarkably, though, it appears that whatever the primitive atmosphere's exact nature, the heavy bombardment played an important role in stocking the primordial soup of organics available for the origin of life. If the atmosphere was methane- and ammonia-rich, the heavy bombardment produced organics copiously by shock chemistry in the atmosphere. If the atmosphere was far less hospitable for organic chemistry, composed of carbon dioxide and nitrogen, say, then the asteroids and comets responsible for the heavy bombardment, and the ever-present interplanetary dust particles, may have played a key role by providing organic-rich dust to seed Earth's ancient surface.

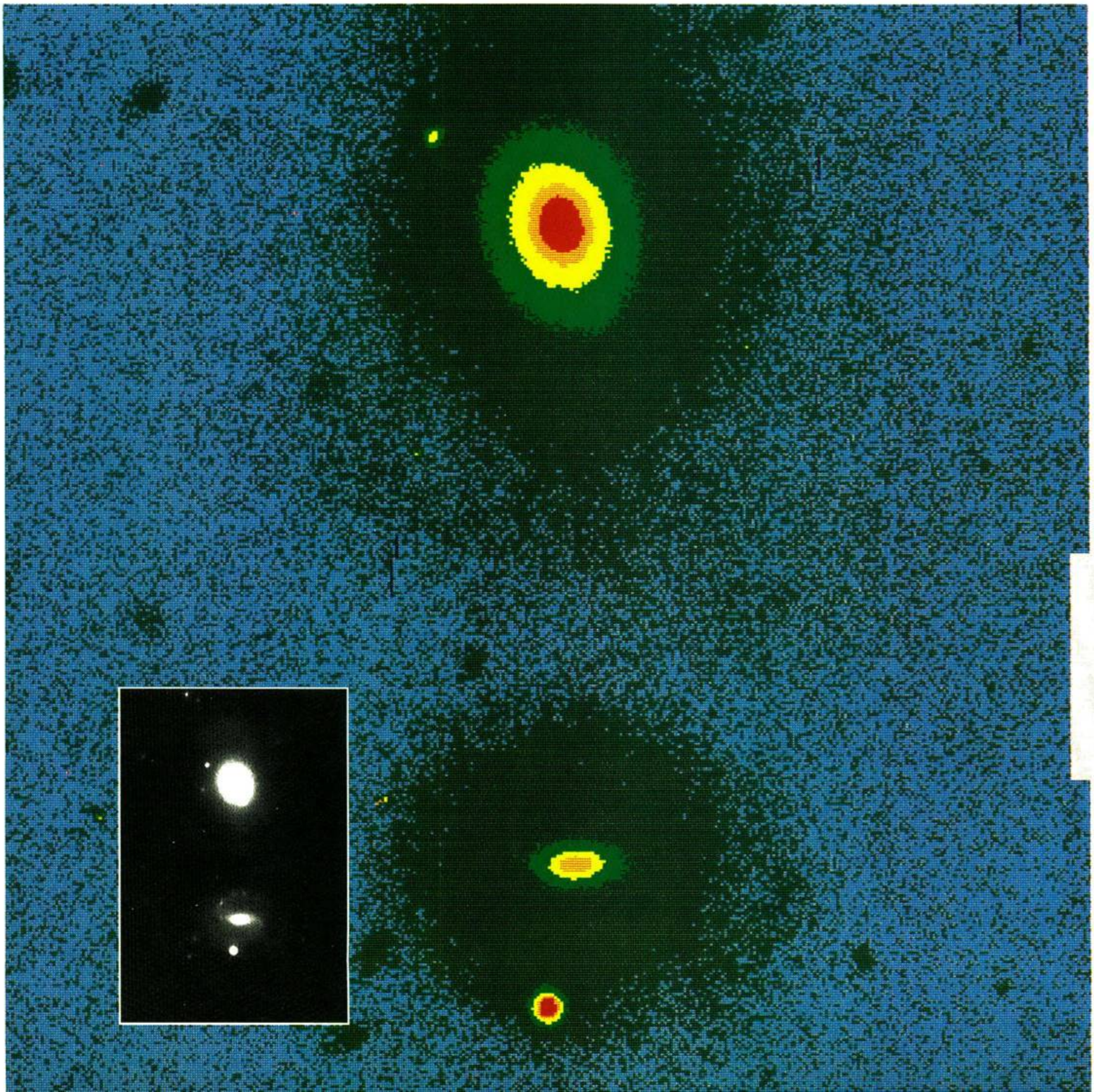
Either way, the case for an important extraterrestrial connection for the origin of terrestrial life is too intriguing to ignore. □

Christopher Chyba is a National Research Council Scientist at the NASA Ames Research Center. He recently completed his doctoral thesis with Carl Sagan of Cornell University on the topic of the heavy bombardment and the origin of life.

ODD COUPLES

Astronomers propose new ideas on the birth of spiral-elliptical galaxy pairs.

Text and images by Jack W. Sulentic



Lars Hernquist and Joshua Barnes: computer simulation of encounter of two disk galaxies

Over the past twenty years, astronomers have found a growing body of evidence that galaxies do not like to live alone. In addition to rich clusters of galaxies, it appears that space contains many loose groups whose gravity helps tie together the clusters, making the observed supercluster structure of the universe. Astronomers find no uniform background of isolated galaxies: in fact, large voids exist where galaxies are almost entirely absent. But scattered through regions of space that contain few galaxies are many binary galaxies — galaxies that travel in gravitationally bound pairs.

Most of these pairs formed in the same way as the galaxies in clusters did billions of years ago. But many unusual pairs exist — those containing a spiral and an elliptical galaxy. These mixed pairs stretch the limits of our understanding about how galaxies are shaped and formed.

MIXED PAIRS CONTAIN the unlikely combination of an elliptical and a spiral galaxy, as seen in these false-color and black-and-white images of pair 104 (AM 2312-511). The pair may have formed in a past merger of a group of galaxies.

Galaxy Pairs

Normal galaxy pairs seem to be a natural laboratory for studying the fundamentals of galaxy structure. Studies of the motions of the galaxies orbiting about one another yield maps of the distribution of mass in the outer halos of the galaxies. By observing galaxies in isolated pairs, astronomers remove the influence of other effects on the pair and can determine how each galaxy's gravity deforms its partner's shape.

Swedish astronomer Erik Holmberg produced the first catalog of binary galaxies in 1937. Fritz Zwicky, a Swiss astronomer living in the United States, also helped to pioneer the study of paired galaxies in the 1930s and 40s. Important atlases of these galaxies were published by the Soviet astronomer Boris Vorontsov-Velyaminov and American astronomer Halton Arp. These atlases show that paired galaxies are quite numerous. Igor Karachentsev's 1972 catalog of pairs in the northern half of the sky contains more than 600 pairs brighter than magnitude 15.7. About 10 percent of all galaxies in the loose-group regions of space are members of binaries.

There are too many isolated pairs for them to have formed by random encounters between single, unrelated galaxies. Flyby pairs in the denser clusters of galaxies do occur, but chance encounters between isolated galaxies are extremely rare. The only possible explanation for the large population of isolated pairs is that the galaxies must have been born together.

Spiral, Spiral

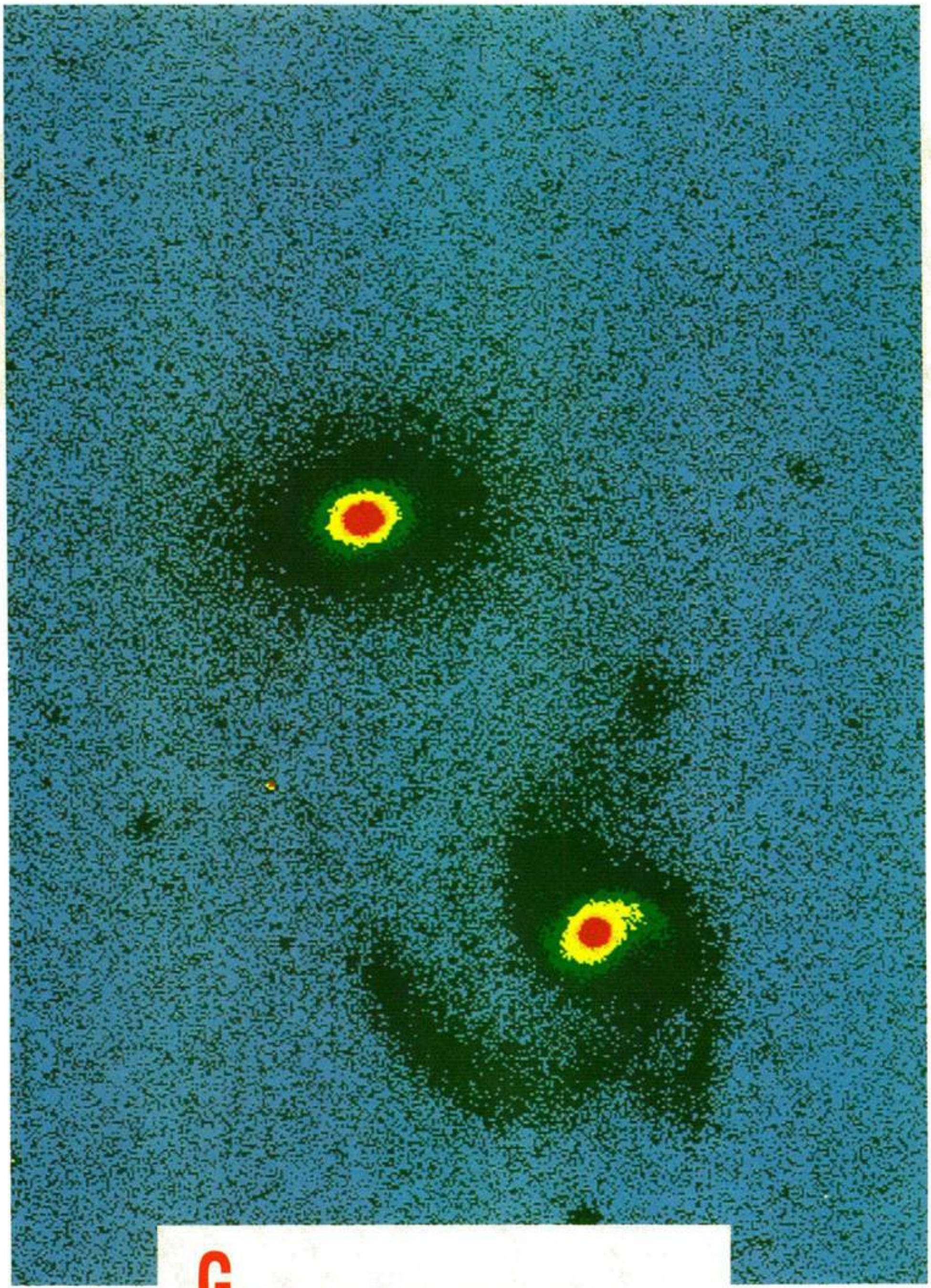
Current ideas indicate that local conditions control whether a galaxy becomes a spiral or an elliptical. Galaxies in isolated pairs should have similar properties because they formed from the same swirling gas. Like paternal twins, the galaxies might exhibit some differences in mass or size, but they should have similar shapes. Spiral galaxies should be paired with spirals and ellipticals with ellipticals.

Observations show that this pairing of similar shapes does indeed occur. The galaxies in many of these matched pairs are more similar than researchers first expected. Also, as Holmberg pointed out, the colors of the paired galaxies in his study are similar. If one galaxy is bluer than normal, then its companion tends to be bluer than normal as well.

But a complete sampling of galaxy pairs offers a surprising view. These results differ from the general spiral-spiral and elliptical-elliptical picture: about 20 to 25 percent of the pairs show *mixed* galaxy types. These mixed pairs have a spiral and an elliptical.

Mixed pairs aren't just flukes. The percentage of pairs is much larger than the number expected from occasional random encounters of unrelated galaxies. And many of these mixed pairs show evidence for gravitational interactions between the galaxies. Hence they appear to be physical systems.

The existence of mixed pairs presents a challenge for astronomers trying to understand how two galaxies of different types could form from the same cloud of gas. Spirals and ellipticals are different in two fundamental ways. First, the star formation histories of these two types of galaxies are different. Ellipticals converted almost all of their gas and dust into stars long ago while spirals continue to convert this material into stars at a leisurely rate. Secondly, ellipticals do not show rotationally flattened disks

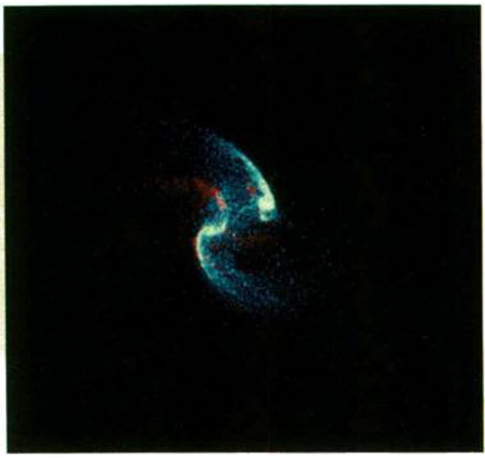


GRAVITY DISTORTS the arms of the spiral in pair 31 (AM 0300–222). The spiral has an inner and outer set of arms and discontinuous arm components, suggesting it is strongly disrupted by its partner's gravity.

while spirals do. This reflects different dynamical properties for the two galaxy types. In particular, the motion of the mass of a galaxy about its rotational axis — a property called angular momentum — differs in elliptical and spiral galaxies.

But mixed pairs do occur. If they can't form naturally, something must have changed the shape of one of the galaxies after it formed. A few years ago Roberto Rampazzo of Brera Observatory in Milan, Italy, and I began a program to test this idea by studying the properties of mixed pairs of galaxies.

Looking at Mixed Pairs



We began by selecting a sample of possible mixed pairs from the southern sky survey done by the European Southern Observatory (ESO) and the United Kingdom's Science Research Council. Then we obtained images for 22 of these pairs with a charge-coupled device (CCD) camera mounted on ESO's 2.2-meter telescope in Chile. The illustrations in this article are the results of those observations.

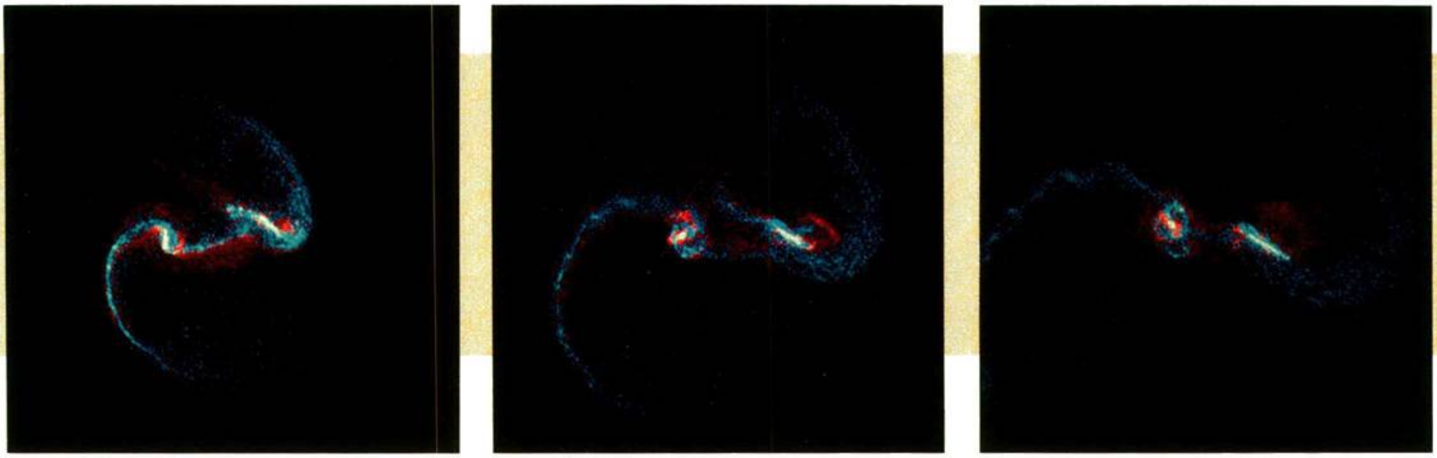
Most of these pairs appear in the catalog by Arp and Barry Madore; only eight appear in the *New General Catalogue* (NGC) or *Index Catalogue*. Astronomers have not studied most of the pairs in any detail.

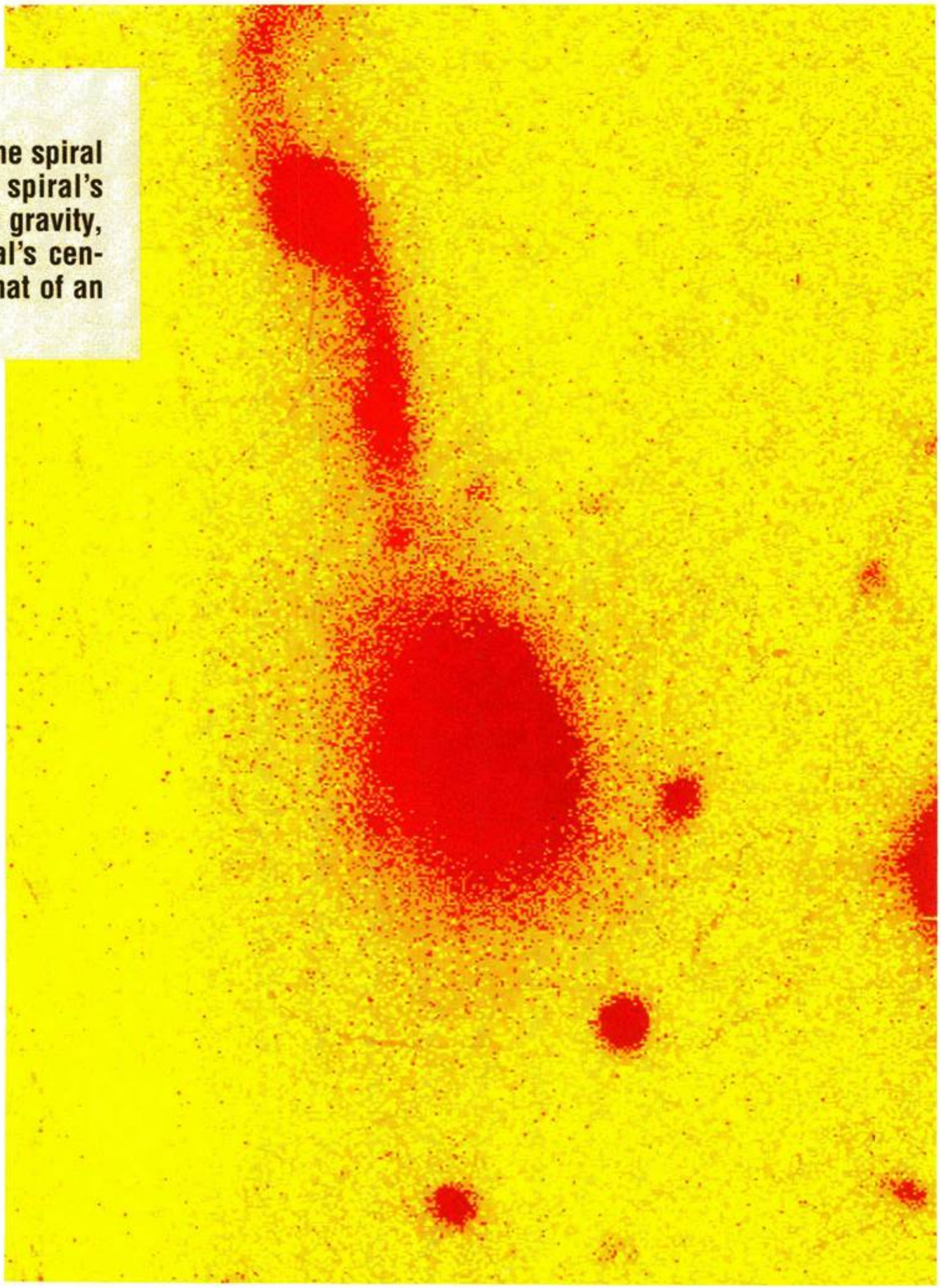
The CCD camera produces standard black-and-white pictures. But to emphasize certain features in the structures of the galaxies, we created false-color images, using one color for each level of brightness in the image. The images on page 36 show black-and-white and false-color representations of the elliptical-spiral galaxy pair numbered 104 in our observing list. Arp and Madore in their list of peculiar galaxies in the southern sky call this pair AM 2312–511 (the numbers give the object's position).

Careful analysis of the shapes of the galaxies in pair 31 (left) shows that it contains one elliptical and one spiral galaxy. It also reveals a clue to the pairs' origin. The distortion of the arms in the spiral member implies that the two galaxies are gravitationally interacting. Detailed study of our 22 pairs suggests that many mixed pairs are gravitationally interacting.

Pulling Apart and Pulling Together

This result presents a possible solution to the mixed-pair problem. Perhaps many of the pairs did not begin as mixed spiral-elliptical pairs but as a spiral-spiral or elliptical-elliptical pair. The gravity of one galaxy, however, changed the shape of its companion.



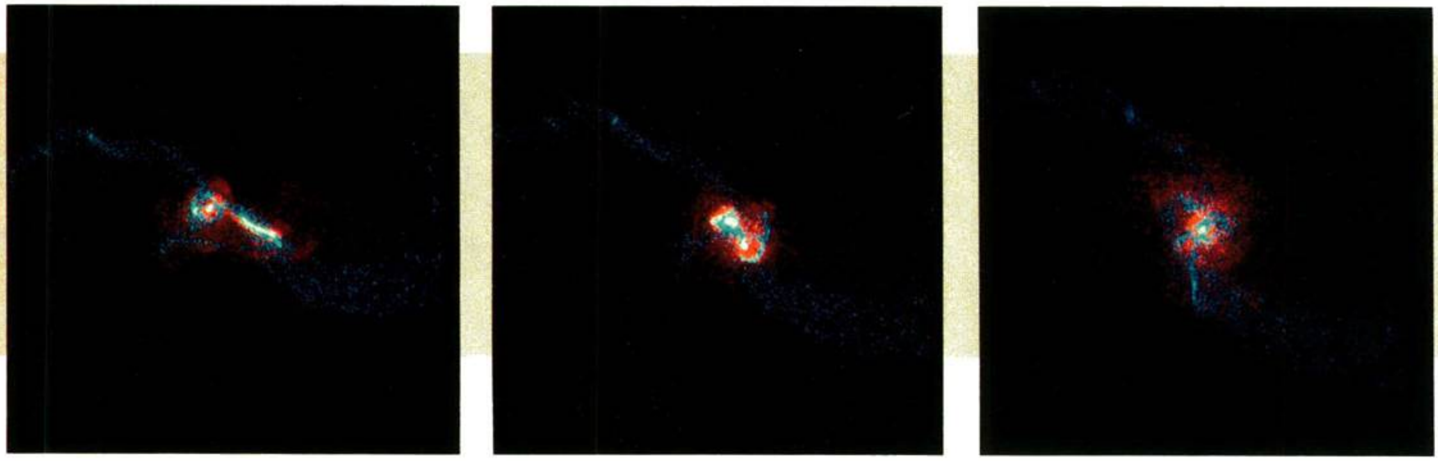


THE ELLIPTICAL DOMINATES the spiral in pair 5 (AM 0012–235). The spiral's arms, created by the elliptical's gravity, have no features, and the spiral's central bulge has a structure like that of an elliptical galaxy.

Galaxies aren't solid objects. They contain a mixture of gas and stars. So a nearby galaxy's gravity can modify or even drastically change a galaxy's shape by deforming the mixture of gas and stars or by tearing the galaxy apart. A near neighbor also can affect the rate of star formation in a galaxy by compressing regions of gas and dust. The resulting burst of bright new stars can make the galaxy appear to have a different shape.

Some of the mixed pairs we observed may have formed with one elliptical and one lens-shaped lenticular, or S0, galaxy. So galaxies have star formation histories like those of ellipticals but possess rotationally flattened disk components like those in spirals. The nearby elliptical in these pairs may have perturbed the lenticular galaxy into a pseudo-spiral galaxy.

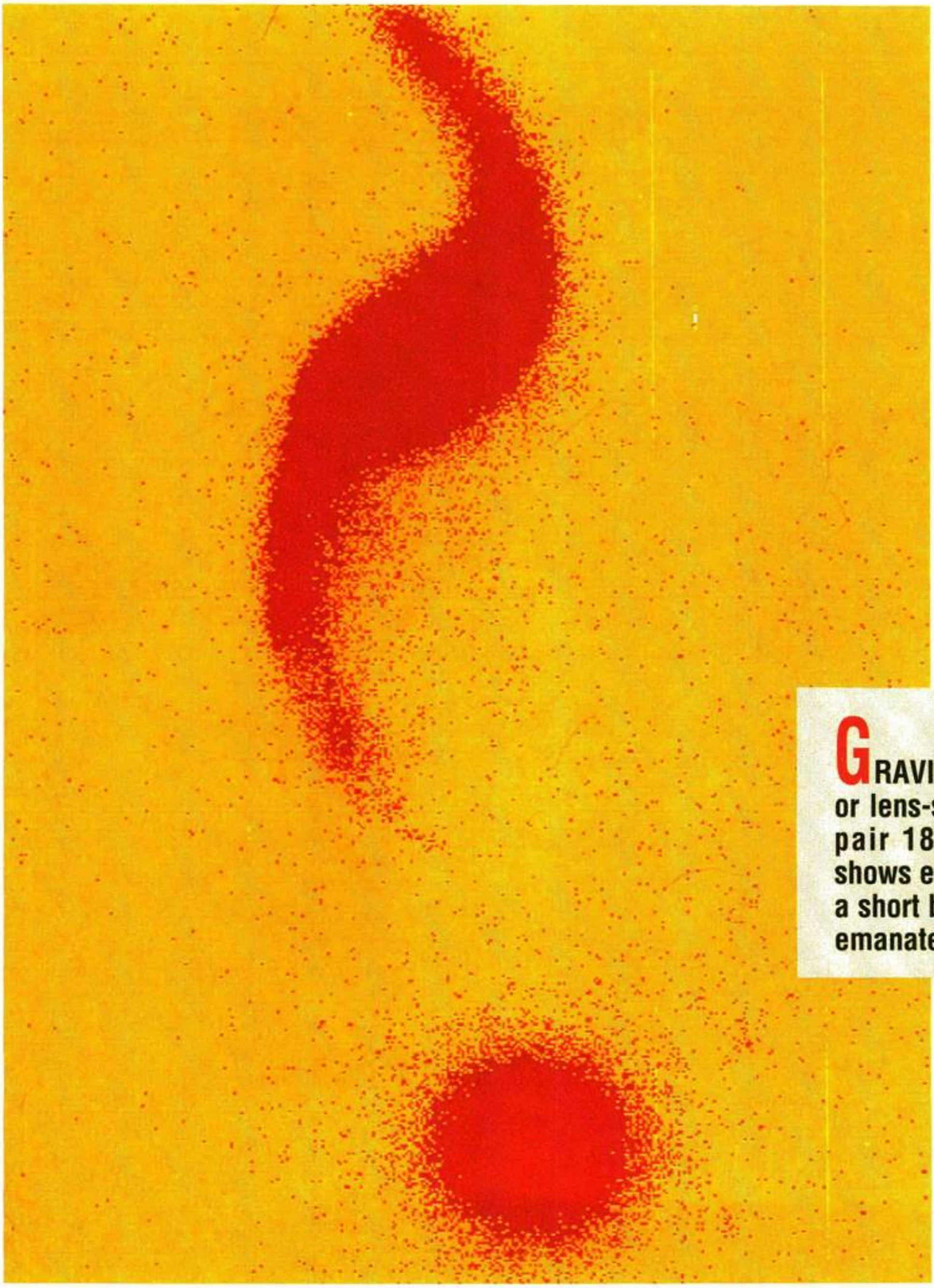
Pairs 5 (right) and 18 (next page) are examples of this kind of gravitational interaction. In these cases the "spiral" arms are too open and too smooth to be similar to the arms seen in normal spirals like the Andromeda Galaxy and Milky Way Galaxy. The elliptical companion may have disrupted the disk component of the lenticular member in these pairs. Computer modeling suggests that, to



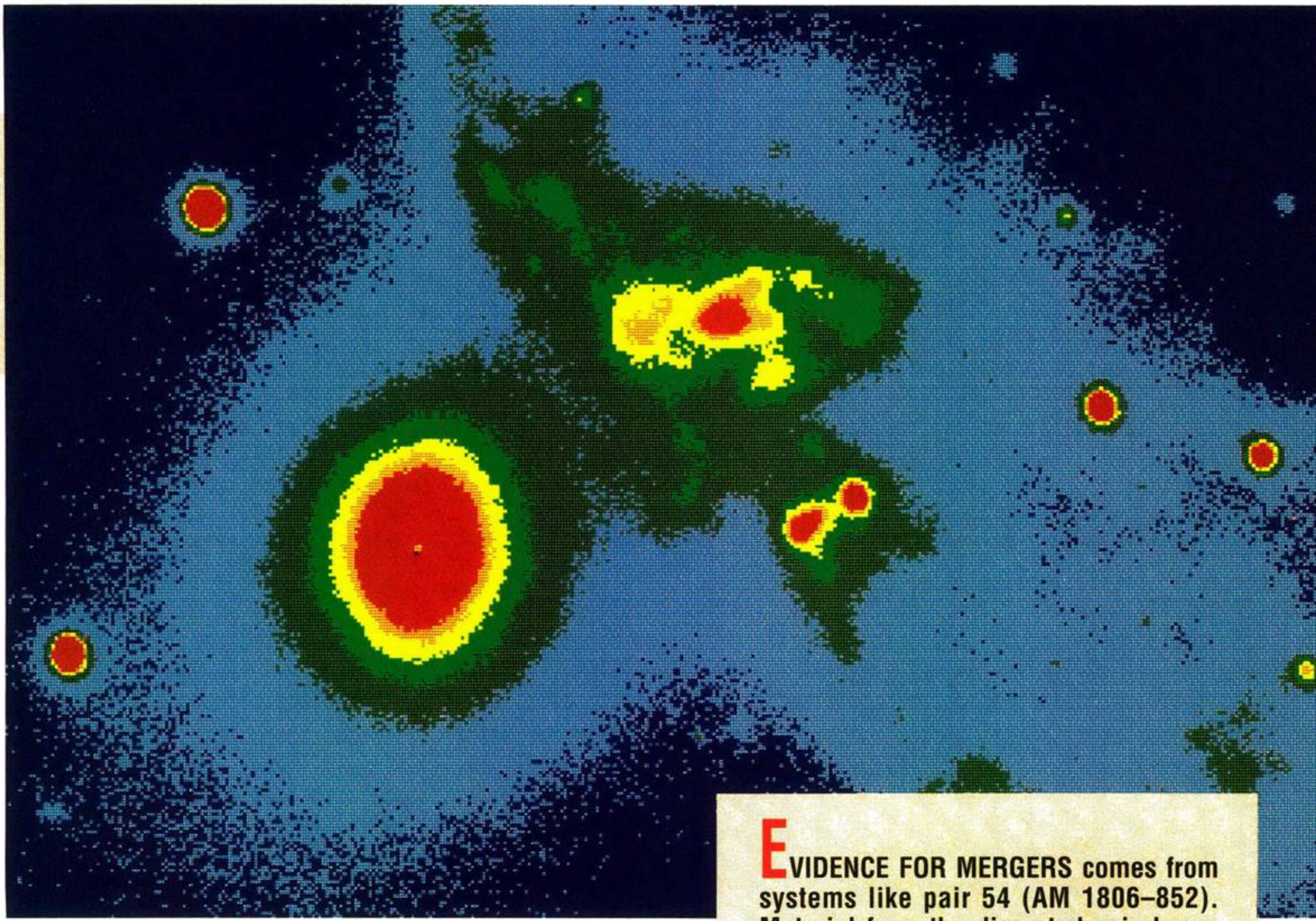
a certain degree, such disruptions can assume the form of long tails that mimic spiral arms. (For an example of these false spiral arms, see the computer simulation of an encounter between two disk galaxies on the top of pages 37-40.) This elliptical-lenticular interaction may account for some mixed pairs — from 3 to 6 of our 22 pairs.

Other mixed pairs may not have originated as pairs at all. They may have originated as members of compact galaxy groups. They are dense groups of from four to eight galaxies that appear to be susceptible to gravitational collapse. Examples of such groups are the famous Stephan's Quintet and Seyfert's Sextet.

If a compact group of spiral galaxies partially merges, then the spiral component of a mixed pair represents the last intact member of the original group while the elliptical is the



GRAVITY TRANSFORMED a lenticular, or lens-shaped, galaxy into the spiral in pair 18 (AM 0119–613). This spiral shows evidence for arm structure and for a short bar from which the arms seem to emanate.



EVIDENCE FOR MERGERS comes from systems like pair 54 (AM 1806–852). Material from the disrupted spiral may someday merge with the elliptical. But such mergers are not frequent enough to explain the number of mixed pairs.

merger product of the other galaxies. Computer simulations of gravitational encounters between several galaxies predict that compact groups merge quickly. After a short time, the end product of the merger of two galaxies — even two spiral galaxies — resembles an elliptical galaxy.

Elliptical galaxies that were involved in mergers often leave telltale signs of the merger event. The arc or shell structures found in the outskirts of the elliptical component of pair 104 may be evidence of a past merger.

Other pairs also show evidence of collisions or mergers in progress. While researchers can never be certain, some of these systems may be in a state of final collapse, with their elliptical component being produced in an earlier merger of other galaxies. Pair 54 (above) exhibits a catastrophic disruption of what may have been a spiral galaxy. Such a disrupted galaxy may end up merging with its elliptical neighbor. Another observed pair shows an even more complicated system composed of at least three galaxies. The dominant elliptical galaxy may be in the process of dining on its neighbors. The system's extensive network of bridges and filaments suggests that galaxies are coalescing.

Forming a Better Picture

The observed distorted shapes of galaxies in mixed pairs imply that gravitational encounters are taking place. An elliptical galaxy's gravity may disrupt a lenticular into a spiral shape or the merger of galaxies in a compact group may reduce the group to a mixed pair.

But there still are problems with this picture of how galaxy pairs form. Gravitational encounters begin with a pair composed of an elliptical and a lenticular galaxy. Though the star formation histories of such pairs are similar, their angular momentum properties are not. Thus one of the two problems of mixed pairs — different star formation histories and different dynamical properties — remains to tantalize astronomers.

The merger of compact groups to form pairs requires a steady and plentiful supply of merging compact groups. It is not clear that the universe contains such a large supply of groups to account for most of the isolated mixed pairs seen. While theoretical models support this as a possible process by which mixed pairs can form, the sparsity of observed interacting compact groups of galaxies weakens this idea.

Mixed pairs tell astronomers more effectively than normal pairs that gravitational interaction can produce profound changes in galaxy properties. But at the same time, they continue to present a puzzling array of questions about the effects induced by the interaction of galaxies. ☐

Jack W. Sulentic, an astronomer at the University of Alabama, studies quasars and unusual galaxies. Coauthor of the Revised New General Catalogue, *he wrote about quasars in the October 1984 ASTRONOMY.*

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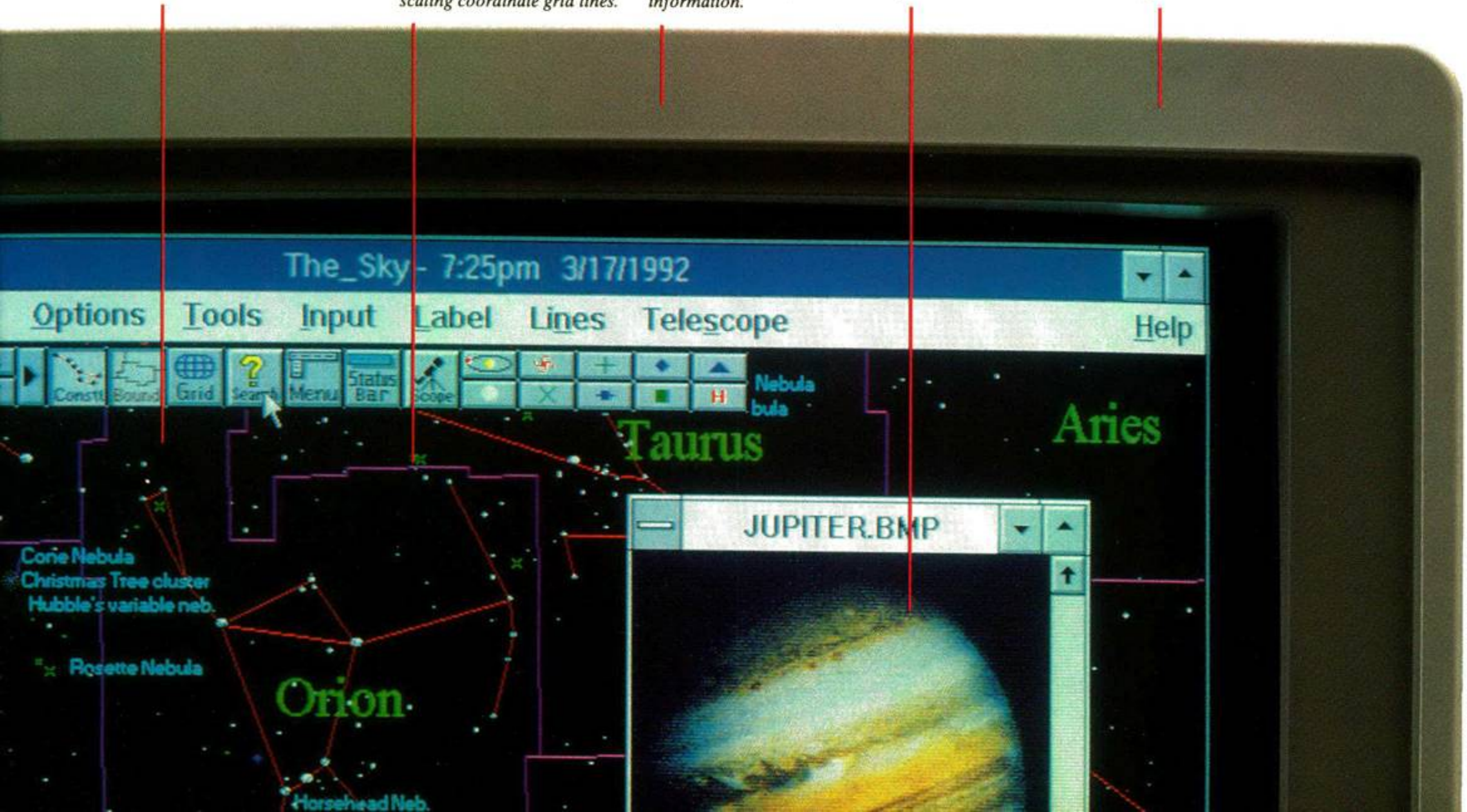
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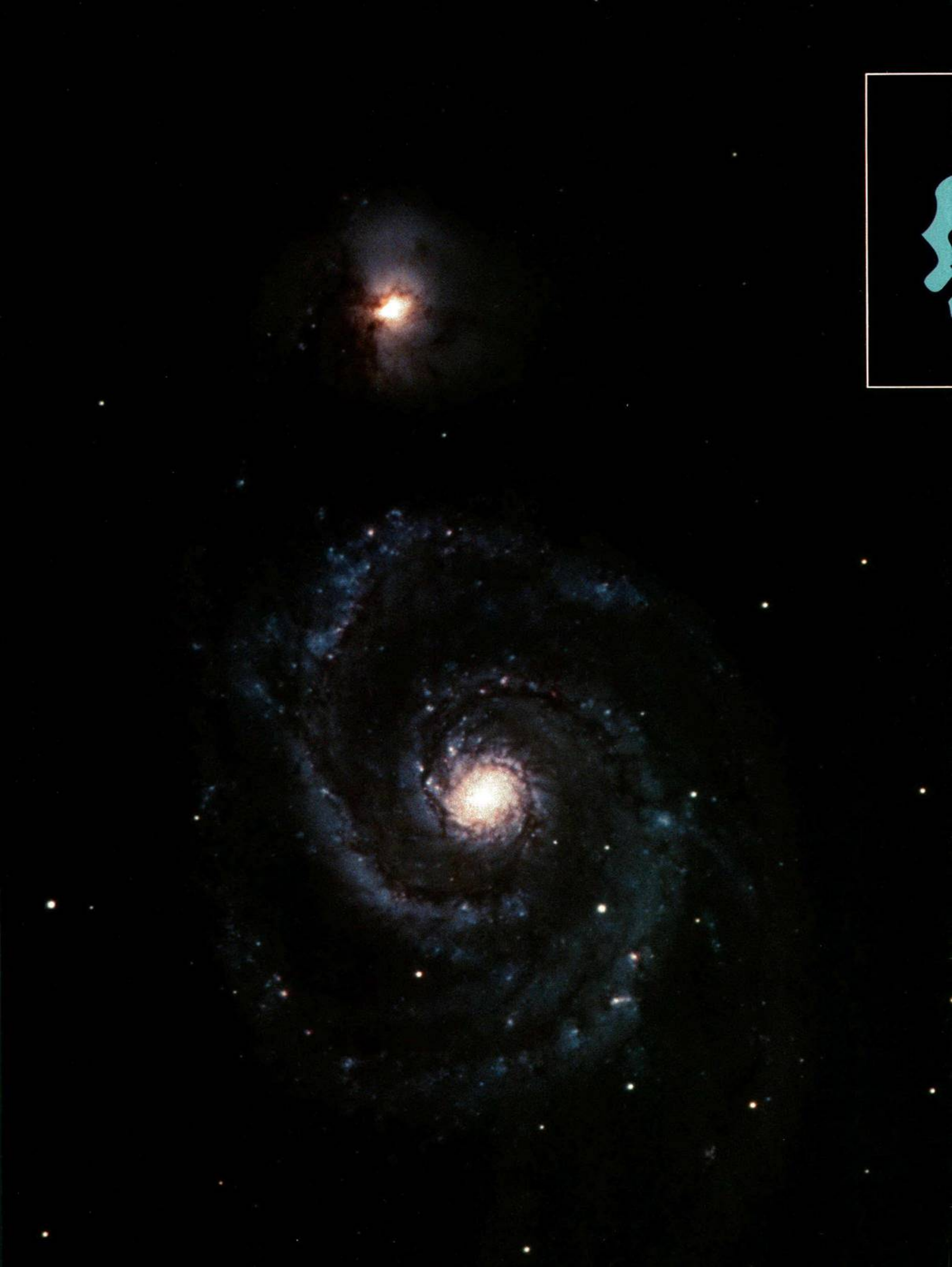

THE REAL UNIVERSE

The GRAND ILLUSION

What we see in the night sky is a wildly misleading representation of the true universe.

by Ken Croswell

What you see is not always what you get. In fact, what you don't see is often closer to the truth — especially in astronomy. Astronomy depends strongly on what we can see and tends to exclude what we cannot. Our telescopes observe distant planets, stars, and galaxies by capturing light. This light may have a wavelength our eyes can see, or it may have a wavelength they cannot, such as infrared or ultraviolet. But whatever the wavelength they observe, our telescopes can't detect radiation from objects that don't produce any. So, intrinsically faint objects are harder to see than intrinsically bright ones, even though the former may be more common. If we think that the most common objects in the universe are those that appear to be the most common, we have been fooled by something we call the *Grand Illusion*.

Welcome to the Grand Illusion

Suppose I want to determine the average annual income of Americans. I want a large sample, one that will give good statistics. So I poll every American who owns a Jaguar.

Am I crazy? Of course. Yet we do the same kind of thing every night we step outside. Innumerable stars and galaxies surround us. The statistics look good. But the sample is horribly biased in favor of objects with the most luminosity, just as the Jaguar poll was biased in favor of people with the most money.

The Grand Illusion begins, in mild form, right here in the solar system. What was the last planet you observed? I bet it wasn't Neptune or Pluto. Instead, it was probably a bright planet like Venus or Jupiter. For a long time, of course, astronomers knew of just six of the nine planets in the solar system, the six that lie closest to the Sun. Only more recently did they discover Uranus, Neptune, and Pluto, worlds that escaped detection because of their great distance and faintness. And there's no guarantee that we aren't missing still more distant planets. (See "Where Has Pluto's Family Gone?" by Alan Stern, September 1992.)

But the solar system is hardly the most extreme example. When we leave the solar system, the Grand Illusion asserts itself with full force: we find the universe turned upside down, for objects that appear most common are in fact the rarest, while those that are difficult to see are by far the most abundant.

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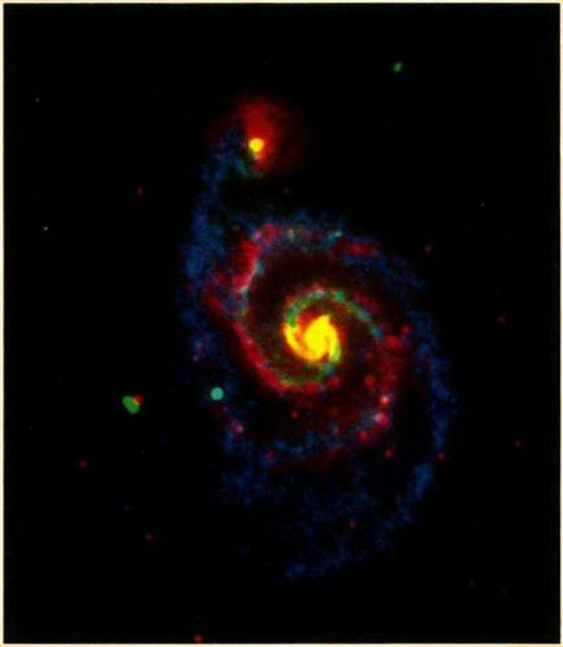

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THE GRACEFUL SPIRAL ARMS so prominent in optical photos of the Whirlpool Galaxy (opposite) belie the fact that at least as much mass inhabits the regions between the arms. At radio wavelengths (above, shown in green and blue), you can begin to see this normally hidden matter.

Superstars

The Grand Illusion really rears its head when we study stars. Stars range in luminosity from superstars emitting a million times more visible light than the Sun to dim dwarfs giving off only a millionth of the visible light of the Sun. Guess which are easier to see.

When you think of stars, you probably think of bright ones like Sirius, Rigel, Betelgeuse, and Antares. These stars are bright and conspicuous, and most stargazers learn them soon after beginning to explore the sky. All are also intrinsically much brighter than the Sun, and their immense luminosities mislead many into thinking our Sun is only a modest star. Indeed, many astronomy textbooks deride the Sun as "average" or "run-of-the-mill," when it's really neither.

The brightest stars fool us into thinking the Sun is a minor star. Take, for example, the 25 brightest stars in the night sky. Every one radiates more light than the Sun. Of these 25 stars, nine are hot, blue-white B-type

BIG, BRIGHT, AND BEAUTIFUL, the Andromeda Galaxy (M31) is the showpiece of the Local Group. But don't think of M31 as average. Far more typical — in the Local Group and the universe as a whole — are dwarf galaxies such as NGC 185, Sextans A, and Leo II.

Tony Hallas and Daphne Mount

stars — such as Regulus in Leo, Spica in Virgo, and Rigel in Orion. These B stars vastly outshine the Sun. For example, Regulus produces as much visible light in a day as the Sun emits in four months, whereas Rigel gives off as much visible light in an hour as the Sun generates in six years.

Six of the 25 brightest stars are hot, white A-type stars — such as Sirius in Canis Major, Vega in Lyra, and Deneb in Cygnus. Each of these six stars exceeds the Sun's luminosity. Another seven stars are cool giants with spectral types of G (yellow), K (orange), or M (red). They include the G-type giant Capella in Auriga, the K-type giants Arcturus in Bootes and Aldebaran in Taurus, and the M-type supergiants Betelgeuse in Orion and Antares in Scorpius. All these stars are far more luminous than the Sun.

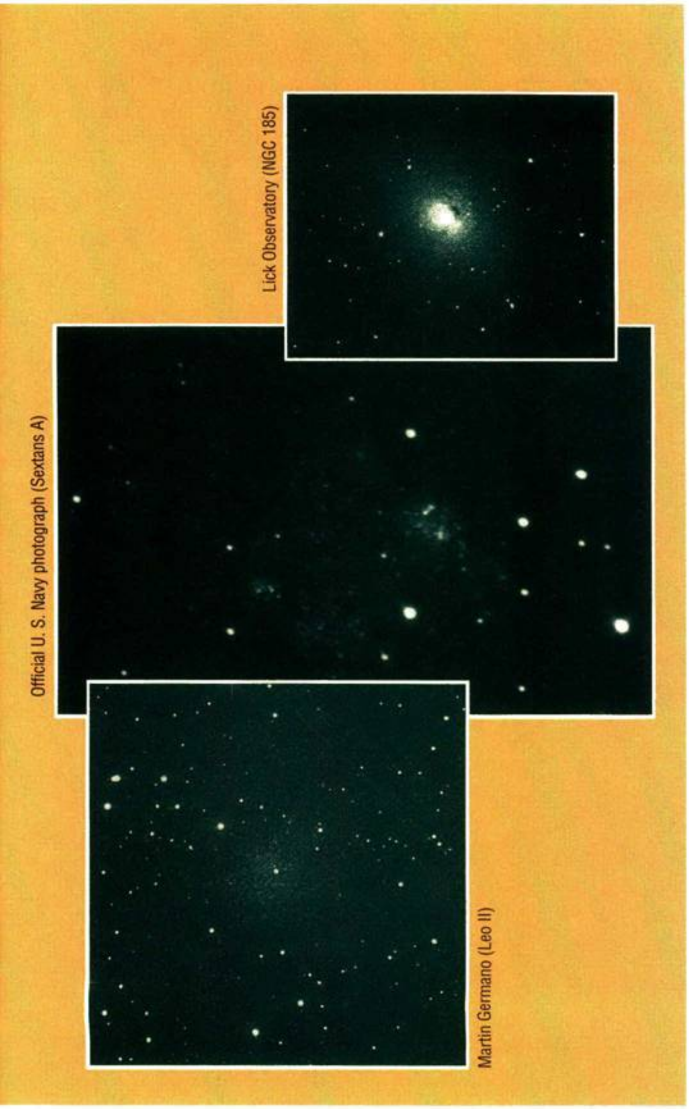
Altogether, then, B-type stars, A-type stars, and cool giants account for 22 of the 25 brightest stars. The other three stars in the sample also outshine the Sun — Canopus in Carina, Alpha Centauri in Centaurus, and Procyon in Canis Minor. Of the 25 brightest stars, only one — Alpha Centauri A — is a G-type main-sequence star similar to the Sun. Yet even it radiates more energy than the star we orbit.

And things don't change much when we take a larger sample. Approximately 500 star systems have apparent magnitudes brighter than 4.00. Of these systems, only three — Tau Ceti, Epsilon Eridani, and the quadruple star Xi Ursae Majoris — are intrinsically fainter than the Sun. The rest, a total of 99.4 percent, are intrinsically brighter than the Sun.

That's the illusion. The reality, though, is that nearly all stars in the Galaxy are intrinsically *fainter* than the Sun. Consider the stars that lie closest to us in space. Nearby stars are the best stars to sample because we select the stars not for how bright they appear but for how close to the Sun they are. Because every star follows its own orbit around the Galaxy, stars that happen to be close to us right now represent a random selection of stars from the Galaxy.

Examine the nearby star sample (see page 48) and you are in for a surprise: the stars that make such a big splash in the night sky — B stars, A stars, and cool giants — are almost completely absent. Instead, we find that about 70 percent of nearby stars are red dwarfs. These diminutive stars are much cooler and fainter than the Sun. The three red dwarfs closest to the Sun are Proxima Centauri, Barnard's Star in Ophiuchus, and Wolf 359 in Leo. Even though they lie within just 8 light-years of the Sun, all three red dwarfs are invisible to the naked eye. *In fact, not a single red dwarf can be seen without optical aid.*

Of the remaining 30 percent of nearby stars, about half are orange, K-type dwarfs. K dwarfs are brighter



Lick Observatory (NGC 185)

Official U. S. Navy photograph (Sextans A)

Martin Germano (Leo II)

and hotter than red dwarfs but fainter and cooler than the Sun. Though K dwarfs account for about 15 percent of all stars, just a few can be seen with the naked eye. Two that can be glimpsed without optical aid are Epsilon Eridani and the double star 61 Cygni. Another 10 percent of the nearby stars are white dwarfs, which are small, dying objects that are also fainter than the Sun. The closest white dwarfs are Sirius B and Procyon B, but neither they nor any other white dwarf is visible to the naked eye.

When we add up red dwarfs (70 percent of all stars), K dwarfs (15 percent), and white dwarfs (10 percent), we find that at least 95 percent of all stars in the Galaxy are intrinsically fainter than the Sun. Rather than being totally outclassed by the superstars, our Sun is in many ways a superstar itself, ranking in the top five percent of all stars in the Galaxy. But you'd never guess it from a casual look at the night sky.

Fooling Yourself

Stars make up galaxies. If stars can fool us, then so can entire galaxies. Take a look, for example, at the beautiful Whirlpool Galaxy (M51), which lies near the end of the Big Dipper's handle. The Whirlpool is a giant spiral like our own Milky Way Galaxy. You can see the bright spiral arms wrapped around the galaxy's nucleus, and you can also see the dark interarm regions between the spiral arms. The spiral arms are bright because that is where the stars are, whereas the interarm regions are dark because no stars lie there. Right?

Wrong. Actually, and incredibly, the dark interarm regions harbor nearly as many stars as the bright spiral arms do. The spiral arms appear bright because they contain extremely luminous stars like Rigel and Deneb, whereas the interarm regions do not. Even in spiral arms, such extremely luminous stars are rare, but they vastly outshine their lesser brethren and light up the spiral arms for us to see. The spiral arms appear prominent not because they have more stars but because they hog all the extremely luminous ones.

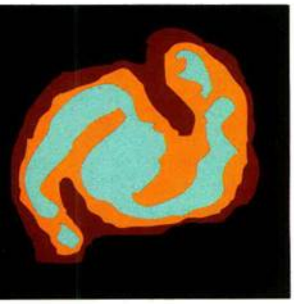
The reason for this inequity is twofold. First, stars are born in spiral arms. Second, extremely luminous stars like Rigel and Deneb burn their fuel fast and die young. Luminous stars therefore die before they can drift out of the spiral arm that created them. This is why the spiral arms contain all the most luminous stars.

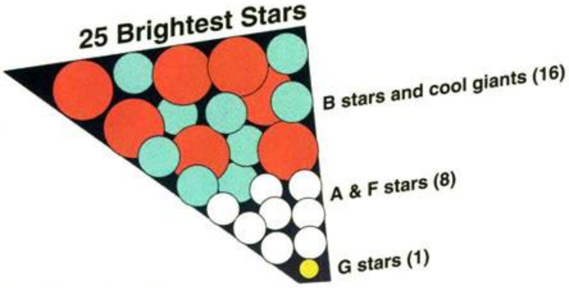
Yet the Grand Illusion determines more than just which parts of a galaxy we see. It also dictates which galaxies we see at all. When you think of galaxies, you probably think of objects like the Whirlpool Galaxy, the giant elliptical galaxy M87, the Andromeda Galaxy, and our own Milky Way Galaxy. These are, after all, galaxies that are easy to observe. But are they typical?

Don't fool yourself. All four galaxies are giants, far bigger, brighter, and more massive than most galaxies in the universe. Just as our Sun is far above the stellar average, so our Galaxy is far above the galactic average. Most galaxies are so faint and puny that even professional astronomers armed with huge telescopes have trouble seeing them when they lie far away.

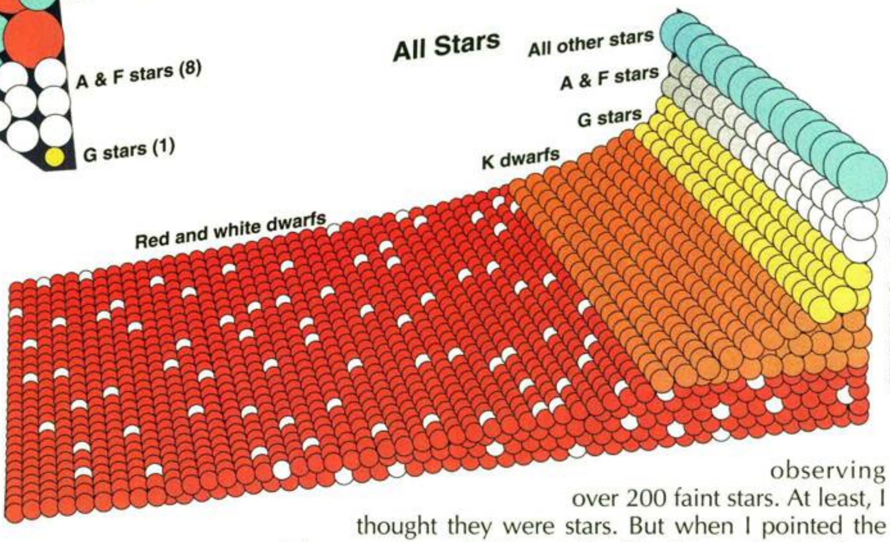
As with stars, the best galaxies to probe are those closest to us, because we can see extremely dim galaxies only if they lie nearby. The nearest galaxies are the members of the Local Group, a collection of about 30 galaxies that includes the Milky Way. Of these 30 galaxies, only two are superpowers: Andromeda, the biggest, and the Milky Way, the second biggest. All other Local Group galaxies are fainter, and most are satellites of either Andromeda or the Milky Way. The Milky Way has ten known satellite galaxies that revolve around it the way satellites orbit Jupiter. Of the Milky Way's satellites, the two most famous are the Large Magellanic Cloud and the Small Magellanic Cloud, but even these aren't typical galaxies. The Magellanic Clouds are smaller than the Milky Way, which sometimes misleads us into thinking they are small galaxies. But they aren't. The Magellanic Clouds appear small only because we compare them with a giant galaxy — our own. The Large and Small Magellanic Clouds actually have luminosities that place them above the galactic average.

To reach truly typical galaxies, we must work harder. The other eight satellites of the Milky Way are dwarf elliptical galaxies. These dwarf galaxies are so faint that astronomers did not even discover them until well into the twentieth century. In 1938, American astronomer Harlow Shapley discovered the first dwarf satellite, which lies in the southern constellation Sculptor. The Sculptor dwarf measures about 8,000 light-years across and harbors just a few million stars, a far cry from the hundreds of billions of stars that compose the Milky Way Galaxy. The Sculptor dwarf was so minuscule that Shapley at first thought it was





JUDGE OUR GALAXY by its brightest stars and you'd be making a big mistake. Hot B, A, and F stars along with cool giants make up most of the brightest stars (left), but cool K dwarfs and red dwarfs and hot but small white dwarfs account for 95 percent of all stars (below).



ASTRONOMY: Steven Davis

merely a smudge on a photographic plate. Only when another plate showed the same smudge was Shapley convinced that the Sculptor galaxy was real.

We now know that dwarfs such as the one in Sculptor are the most common type of galaxy in the universe. Since Shapley's discovery, astronomers have found additional dwarf satellites orbiting the Milky Way. Several of them are so dim that the brightest *single* star in the Milky Way outshines them. Still less luminous galaxies may exist, and you can probably guess why they haven't been found.

For galaxies, though, the Grand Illusion is trickier than it is with stars, because more than just luminosity determines how easy a galaxy is to detect. A massive and luminous galaxy can be missed simply because its surface brightness is too low or too high. Surface brightness measures how much light a galaxy puts out per area of the sky. If a galaxy is too spread out, it will have a low surface brightness no matter how luminous the galaxy is. Such a galaxy will fade into the background sky glow, and we'll never see it. But the opposite extreme is just as bad: if a galaxy is too concentrated, it will look like a star, and again astronomers will miss it.

The scary thing is that nearly all known galaxies have a surface brightness that falls within a narrow range. The galaxies we know about aren't so spread out that they fade into the night sky, but they also aren't so concentrated that they masquerade as stars. Maybe this is how galaxies really are. Or maybe we are missing most of the galaxies in the universe.

Take, for example, galaxies with low surface brightnesses. The dwarf satellite galaxies of the Milky Way are examples of these, but we may be overlooking more than just puny objects. In the mid-1980s, astronomers discovered a low-surface-brightness galaxy in the constellation Virgo. Named Malin 1, this galaxy is no dwarf. It is bigger than the Milky Way, yet its low surface brightness kept it from being detected for many years. Astronomers have since found dozens of giant low-surface-brightness galaxies and several hundred smaller galaxies with a low surface brightness.

The opposite type of galaxy — those so concentrated that they look like stars — may also be common. I ran across several while working on my thesis, which actually had nothing to do with galaxies. Instead, I was searching for distant stars in the Milky Way. I began by observing over 200 faint stars. At least, I thought they were stars. But when I pointed the telescope to my first target, the "star" turned out to be a fuzzy galaxy. About ten percent of the objects in the study proved to be galaxies. It appears that the universe may contain many low- and high-surface-brightness galaxies that have been hiding from us.

For a long time, astronomers have recognized that they are definitely missing out on something: most of the mass of the universe. The outer parts of our Galaxy and other large spirals rotate fast, implying that these galaxies have huge but unseen halos surrounding them. These halos must consist of faint or invisible objects, which astronomers call dark matter. Furthermore, clusters of galaxies would fly apart if the gravity from dark matter did not restrain the galaxies. For these reasons, we now know that the universe has more dark matter than luminous matter. But no one knows what the dark matter is. It could be faint stars, like red dwarfs and white dwarfs, or it could be subatomic particles. Whatever it is, dark matter may be the Grand Illusion in its most sinister incarnation: the universe is full of something that our instruments cannot see.

The Grand Finale

If the Grand Illusion were relevant only to astronomy, non-astronomers could ignore it. But the Grand Illusion is part of life. Every time someone takes a sample and draws conclusions from it, you need to know the biases that went into constructing the sample. Otherwise, the conclusions that emerge could be erroneous. And it doesn't matter if the sample consists of stars or people.

Which reminds me. Lately I've been wondering what the average American car costs. Fortunately, I have a perfect sample to answer this question: all those Jaguar owners. I'll just ask them what they paid.

Am I crazy? You tell me. ☐

Ken Croswell may be crazy — he doesn't even own a car. His last article for ASTRONOMY was "Galactic Archaeology" in the July issue.

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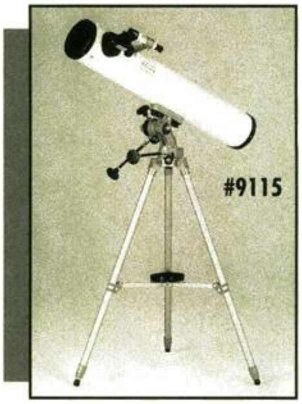

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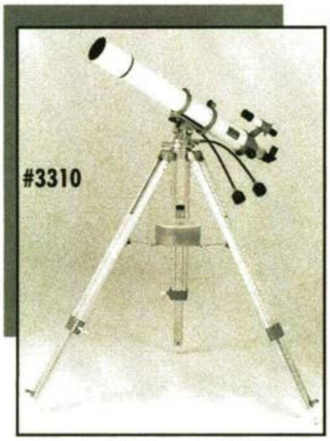

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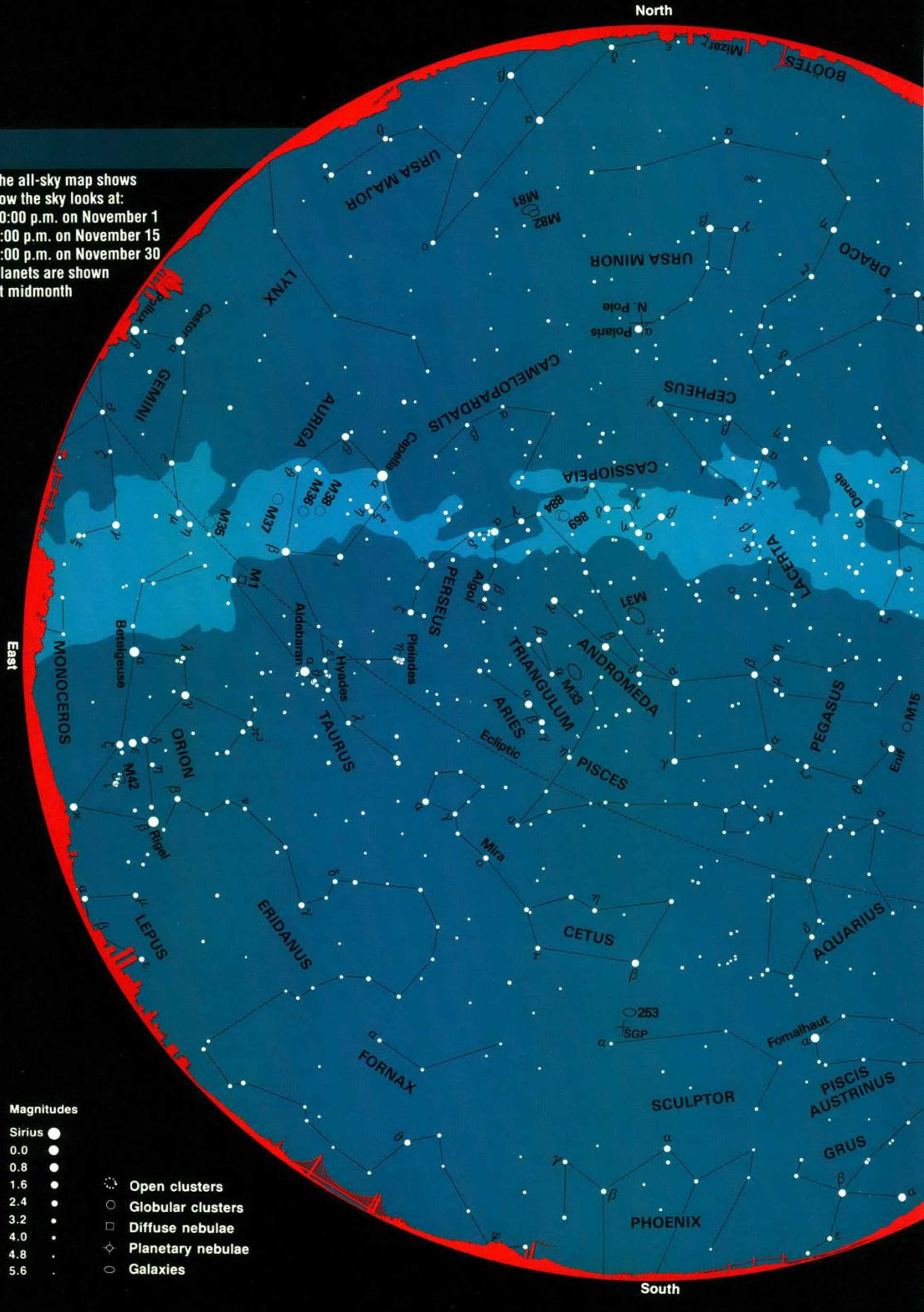
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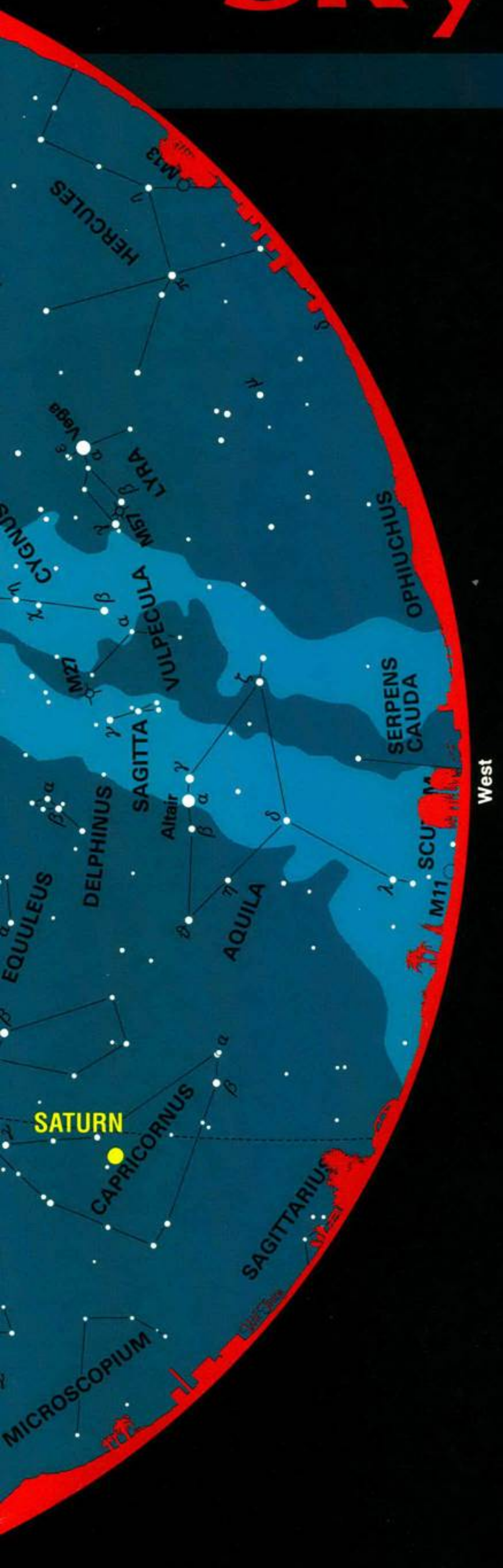
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

The all-sky map shows
how the sky looks at:
10:00 p.m. on November 1
9:00 p.m. on November 15
8:00 p.m. on November 30
Planets are shown
at midmonth

Sky Almanac

November 1992



MARS CROWNS MIDNIGHT SKY

The Red Planet rises late in the evening this month and is high overhead by dawn. As each day passes, Mars grows in size and brightness, making it easily visible as the brightest "star" in Gemini by month's end. Telescopic observers will see dark features on the planet's surface more distinctly as Mars grows larger.

LEONIDS VISIBLE BEFORE DAWN

Despite a Last Quarter Moon hanging low in the sky, observers braving the early morning chill on November 17 and looking straight up can spot as many as 10 to 15 Leonid meteors per hour. The Leonids, a famous meteor shower, on occasion produces a blitz of as many as several hundred meteors per hour.

A MORNING SKY CONJUNCTION

In the predawn sky on November 27 a gathering of planets takes place that includes the Moon, Venus, Uranus, and Neptune. During daylight from North America the Moon passes, in sequence, Uranus, Neptune, and Venus during a three-hour period.

Calendar of Events

2 First Quarter Moon is at 4:11 a.m. EST
Southern Taurid meteor shower peaks
3 The Moon is at apogee (252,836 miles from Earth), 6 p.m. EST
4 Mars passes 5° south of Pollux, 4 p.m. EST
10 Full Moon is at 4:20 a.m. EST
11 Mercury is stationary, 9 a.m. EST
12 Northern Taurid meteor shower peaks
14 Pluto is in conjunction with the Sun, 7 p.m. EST
15 The Moon passes 5° south of Mars, 7 a.m. EST
16 Juno is stationary, 11 p.m. EST
17 Last Quarter Moon is at 6:39 a.m. EST
Leonid meteor shower peaks
18 The Moon is at perigee (231,088 miles from Earth), 7 p.m. EST
21 Mercury is at inferior conjunction, 5 p.m. EST
24 New Moon is at 4:11 a.m. EST
26 Venus passes 1.9° south of Uranus, 7 a.m. EST
27 Venus passes 3° south of Neptune, 8 a.m. EST
The Moon passes 3° north of Uranus, 1 p.m. EST
The Moon passes 1.6° north of Neptune, 4 p.m. EST
The Moon passes 5° north of Venus, 4 p.m. EST
29 Mars is stationary, 11 a.m. EST

Eye on the Sky

by Deborah Byrd

MARS RISES IN MIDEVENING

In November, the Red Planet Mars begins a drama that will continue through this winter. Placed high in the sky and gleaming with a bright orange light, Mars puts on a show that will offer its best views since 1990. Observers armed with binoculars will be able to follow the planet in all its glory throughout the coming months.

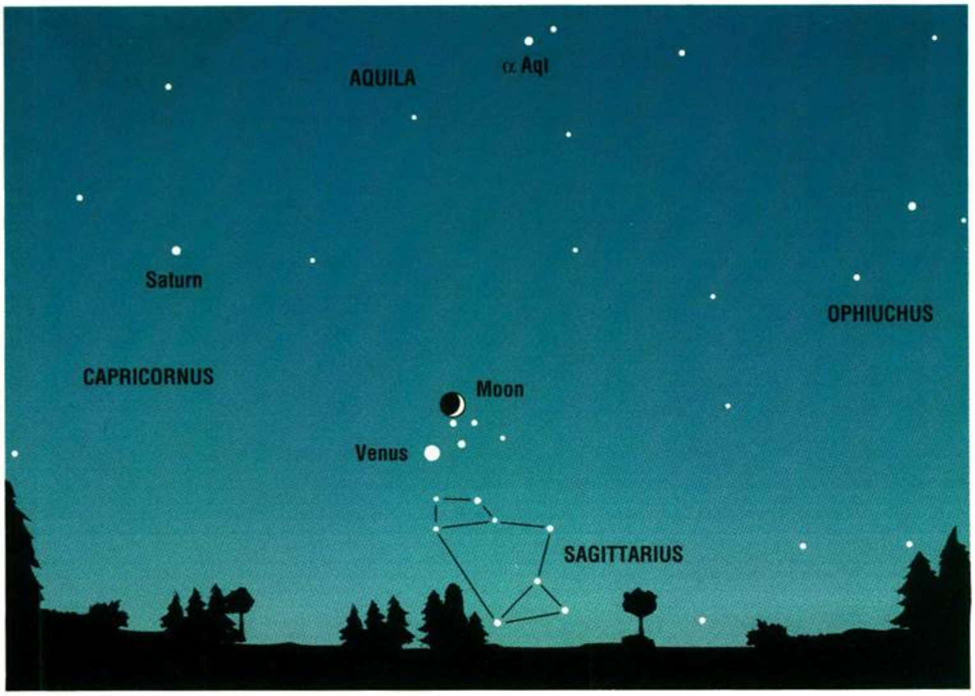
Mars orbits the Sun only one step outward from us, and it's a smaller world than Earth. Its distance from us varies greatly, and this changing distance affects its appearance in our sky. For most any Martian apparition, the planet shines no more brightly than a score of stars. It is a remote reddish dot in our sky that flies rapidly eastward, crossing many constellation boundaries. Now, as Earth prepares to pass between Mars and the Sun, the planet's motion in front of the stars slows down. And in the coming months, Mars will execute a retrograde loop in front of the stars, traveling west as it brightens dramatically and appears prominent in our sky.

By the end of this month, only six objects — the Sun and Moon, the planets Venus and Jupiter, and the stars Sirius and Canopus — shine more brightly than Mars. Mars will be in front of the bright stars of the "winter circle," stars that rise with Mars in midevening. You will easily see Sirius in this group, for it is the sky's brightest star. Mars is the next-brightest object in this part of the sky, and it increases in brightness as the month passes from magnitude –0.2 to magnitude –0.7.

Mars lies 5° south of Pollux on November 4. It appears near the Moon on the night of November 14. Its stationary point comes on November 29. This is when Mars stops moving eastward and begins westward, or retrograde, motion.

As we stand gazing at Mars during this Northern Hemisphere autumn, spring comes to the Red Planet's northern hemisphere. The Martian equinox takes place on November 21.

VENUS LIGHTS UP THE EVENING SKY low in the southwest just after sunset. It is visible above the teapot asterism of the constellation Sagittarius. The Moon passes nearby on November 27.



NOVEMBER METEORS

The Moon gets in the way of both the Taurid meteor shower and the more famous Leonid meteor shower this month. The Taurids reach their broad maximum in early November. The best time to watch for them is in the early morning hours as early in the month as possible. You may see as many as a dozen meteors per hour whose paths across our sky can be traced backward to a single "radiant point" in the constellation Taurus.

After Full Moon on November 10, bright moonlight washes the sky during what are generally the best hours for watching meteors: that is, between midnight and dawn. The light of the Moon will affect this year's Leonid meteor shower, which has a sharper peak than the Taurids, on the morning of November 17. The Leonids are definitely worth watching in the wee hours of November 17, however, because on rare occasions they are among the most active meteor showers.

PLANETS IN NOVEMBER

Venus appears higher in the evening twilight sky this month. It shines brilliantly in the southwest after sunset. The magnitude of Venus is now –4.0, and the planet will get brighter still. You can see Venus even in bright twilight, shortly after the Sun goes down. It sets in a dark sky about two hours behind the Sun when the month begins.

At the end of November, Venus is setting even later. By then it has moved in the sky until it lies almost precisely in front of that region of our solar system now occupied by two distant gas giant worlds, **Uranus** and **Neptune**. Skywatchers have been waiting patiently for the 1993 conjunction of Uranus and Neptune. It will be the first ever seen, because the last time around, Neptune was undiscovered. Uranus was discovered in 1781, and Neptune in 1846. Uranus moves around the Sun in 84 years. It completes an orbit in about half the time Neptune does, not only because it moves faster but also because its orbit is smaller. In January 1993, like spectators in some great celestial Olympics, we'll watch Uranus pass Neptune in the race around the Sun. This event has occurred many millions of times since the solar system formed. But this is the first time we humans will know to look for it.

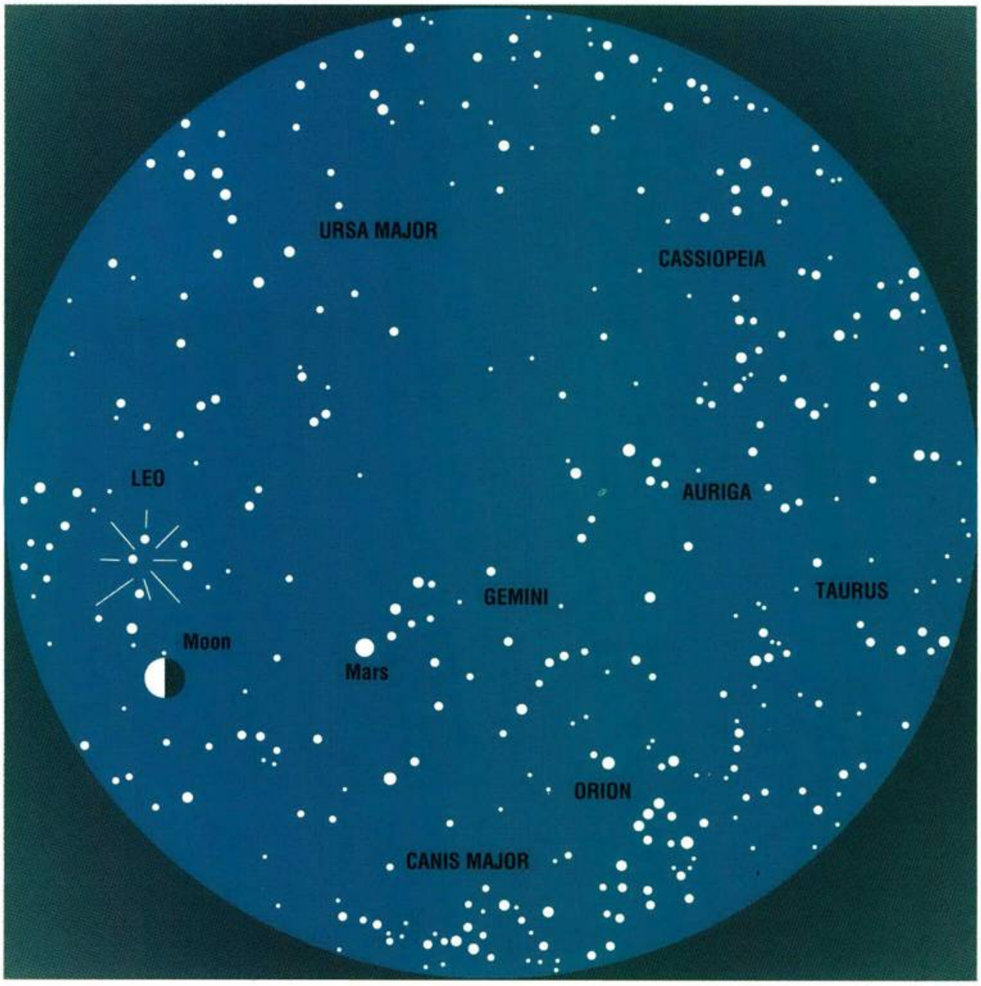
Uranus and Neptune have been edging closer together in the sky for years. This month, Venus sweeps past them both in a single day. Venus passes 1.9° south of Uranus on November 26 and 3° south of Neptune the following day. And the Moon passes them all in only hours. The waxing gibbous Moon is 3° north of Uranus, 1.6° north of Neptune, and 5° north of Venus — all on November 27. If you are gazing at Venus and the Moon that evening, be aware that there's more to this region of the heavens than meets the eye.

Saturn is a gas giant world closer to Earth than Uranus or Neptune. Saturn appears in the south at sunset in front of Capricornus, while Venus is in the southwest in front of Sagittarius. Saturn edges westward throughout the month and fades slightly in brightness. Its magnitude dims from 0.6 to 0.7. The Moon appears near Saturn on the evenings of November 1 and 2 and on November 29.

After Venus sets, while Saturn is descending in the west, **Mars** comes up over the east-northeastern horizon. It is now very bright and prominent and right next to Castor and Pollux, the brightest stars in the constellation Gemini. Mars gets brighter and rises earlier as this month progresses. It also moves with respect to Castor and Pollux. By the end of the month, it forms a straight line with them. Mars begins westward, or retrograde, motion on November 29. The Red Planet is 5° south of Pollux on November 4. It appears near the Moon on the night of November 14. Mars will continue getting brighter and becoming more prominent as it approaches its January 1993 opposition.

Jupiter rises in the east-southeast about three hours before the Sun at the start of November. It is very bright at magnitude –1.8 in front of the constellation Virgo. Jupiter spends the month edging toward the 3rd-magnitude star Porrima in Virgo. It ends the month less than 2° from this star. It's a

Charles F. Capen



THE LEONID METEOR SHOWER on occasion is one of the most active. This year's event is hampered by a Last Quarter Moon, but early on the morning of November 17 you'll see a dozen meteors an hour. The photo (top) shows the incredibly active Leonid shower in 1966.

fine double as seen through telescopes. Be sure to look for Jupiter near the Moon on the morning of November 20.

Lying too close to the Sun, **Mercury** is not visible this month. It passes between the Sun and Earth on November 21. Mercury will return to the predawn sky in December.

THE STARRY SKY

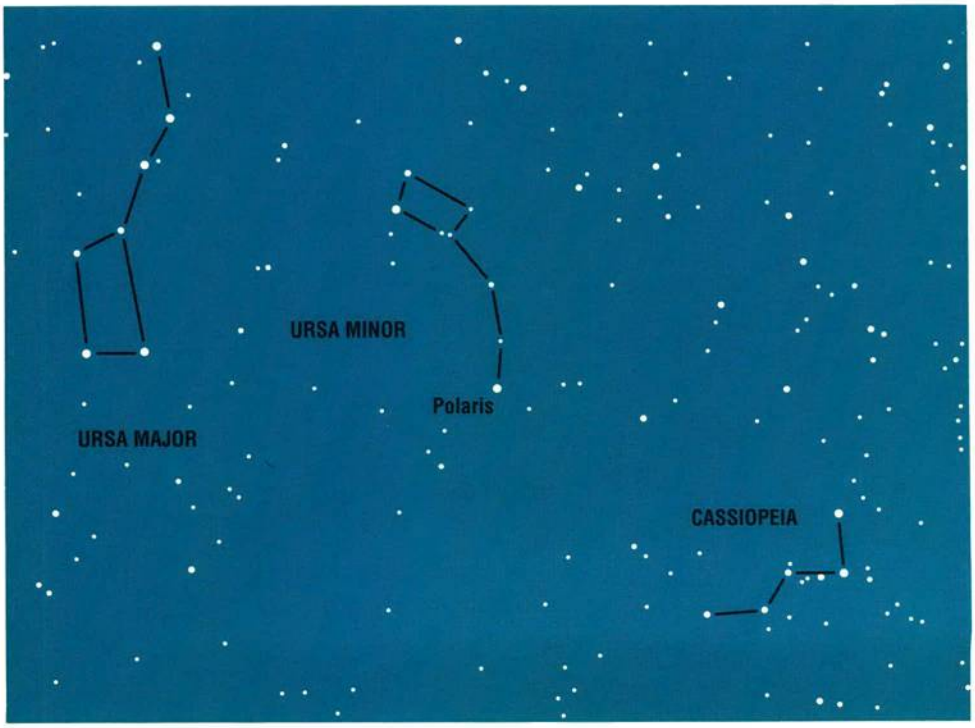
The sky's most steadfast star is Polaris, in the constellation Ursa Minor the Little Bear. Also called the North Star or Pole Star, this is without doubt the most famous star in the sky. Many people mistakenly believe it is also the brightest star in the sky. In fact, it ranks only 49th in brightness. Its importance stems from the fact that it is located nearly at the north celestial pole, the point around which the entire northern sky appears to rotate. While other stars rise and set throughout the night and appear prominent in various seasons, Polaris stays more or less fixed in a single region of the heavens throughout the year.

Polaris was of great importance to early navigators and explorers. It is still a great pleasure to travel either northward or southward on Earth's globe and watch the altitude of Polaris shift accordingly. This star's height above the northern horizon reflects your latitude. It appears 30° high from an earthly latitude of 30° North, 40° up from 40° North, and so on. If you stood precisely at Earth's North Pole, Polaris would be overhead.

Polaris is the brightest star in its constellation at magnitude 2.0. For centuries, in the mythologies of many different nations, this star has been a symbol of constancy. Yet even steady Polaris moves a bit in the sky. That's because it's not located exactly at the pole, but instead a little less than 1° from it. Photographs of the pole taken over several hours reveal that Polaris moves in its own small circle in our sky. What's more, Polaris is not always the Pole Star. Because of precession — a 26,000-year cycle — the position of the true north celestial pole continually shifts among the northern stars. Nearly five thousand years ago, for example, the star Thuban in the constellation Draco was considered to be the Pole Star. Polaris will be closest to the exact pole in the year A.D. 2102.

Our primary legend about Ursa Minor links it to the Great Bear. It seems that Callisto — a beautiful hunter — caught the wandering eye of Zeus, King of the Gods. When Hera — Zeus' queen — discovered the two, she changed Callisto into a bear. Callisto roamed the forest, fearful of both hunters and the other wild animals. She happened to meet a young and handsome hunter and recognized him as her own son Arcas. When she raised up on her hind legs to embrace her son, the boy thought the bear meant to attack him. Luckily, Zeus was looking down on the scene, and he changed Arcas into a bear also. Then he grasped each bear by its tail and pulled until he had lifted both bears into the sky. This legend explains why on old star charts the bears are shown with very long tails. ☐

THE NORTH STAR, Polaris, is the bright star lying closest to the north celestial pole. The constellation Ursa Minor, the Little Bear, swings its way around Polaris as Earth rotates.



Deborah Byrd's radio series, "Earth and Sky," can be heard on stations in the United States, Canada, and Guam.

Through the Eyepiece

by Jeff Kanipe

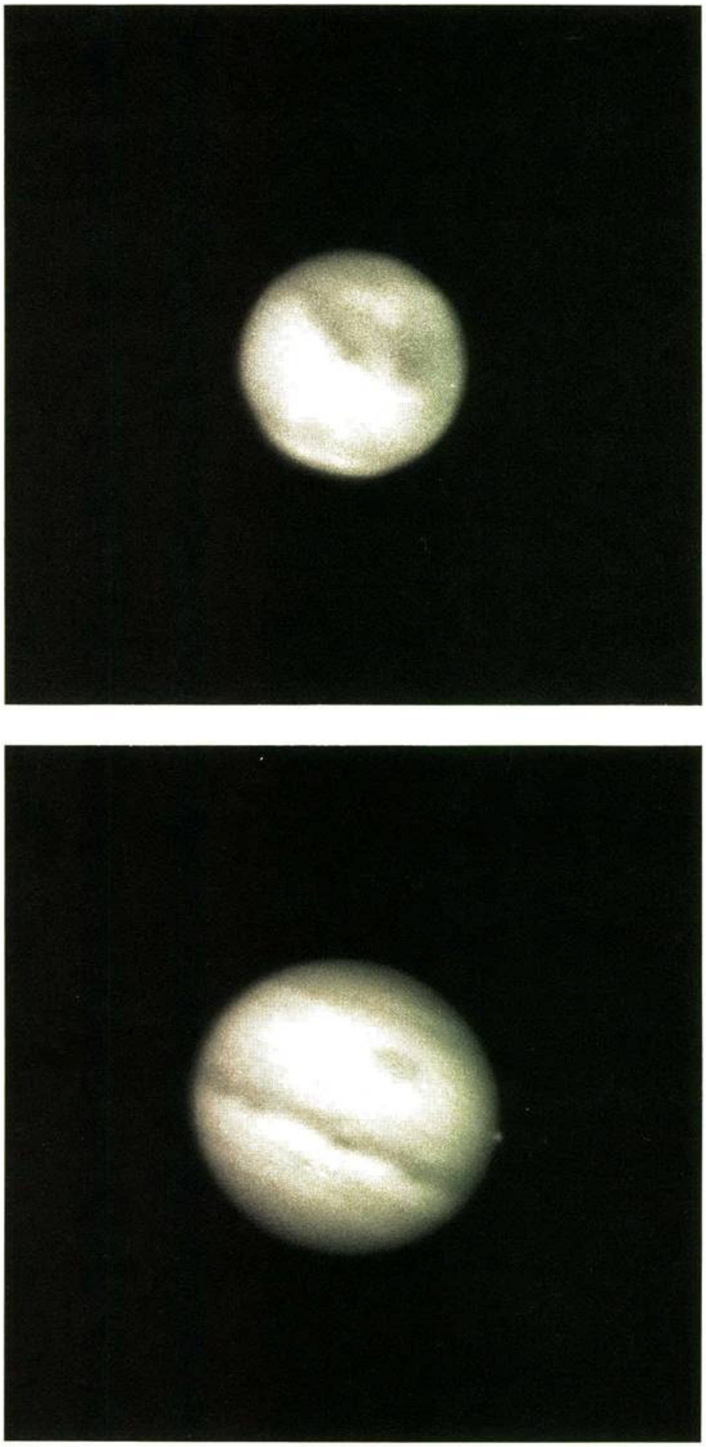
MARS COMES ON STRONG

For months now, **Mars** has been playing with us. We knew it was coming, but for most of the year Mars has been coy, tantalizing us by edging nearer and nearer at a snail's pace. Over the summer months, it rose after midnight and wasn't well positioned for observing until nearly dawn. In September, the planet increased significantly in brightness and size and was at least fairly well placed for telescopic observing in the southeast by midnight.

Now, as Earth and Mars dance toward each other in space, changes in the Red Planet are occurring less *adagio* and more *allegro*. Already, Mars rises by midevening and outshines nearly all the bright stars. Early in November, the Red Planet's apparent equatorial diameter breaks into double-digits — from 9" to 10". It rapidly achieves 11.5" by midmonth and is nearly 13" across by the month's end. The magnitude increases correspondingly over the month, from –0.2 to –0.7. Still, the best is yet to come. Mars comes to opposition January 7, when it will be riding high in the sky with a magnitude of –1.5 and an apparent diameter of 15".

Martian spring begins in that planet's northern hemisphere November 21. Over the next several months, dark surface features will become more pronounced as the polar cap shrinks. This phenomenon, known as the wave of darkening, is part of the Martian seasonal cycle. Mars' rotation axis is tilted 24.9°, which causes the planet to experience seasons similar to those on Earth, except that Martian seasons are about twice as long (and have more extreme temperatures). As the planet nears summer, the northern polar cap, composed of frozen carbon dioxide, begins sublimating — changing directly from a solid to a vapor.

As the polar cap shrinks, the amount of sunlight reflected from the surface decreases, which increases humidity. The features appear to darken gradually from pole to equator — hence the name "wave of darkening." This intensifies over the next several months as the polar cap continues sublimating. Fierce winds created by convective heating shift the sand around on the surface, also helping to make the planet's albedo features darken. This, in simple terms, describes Mars' weather machine.



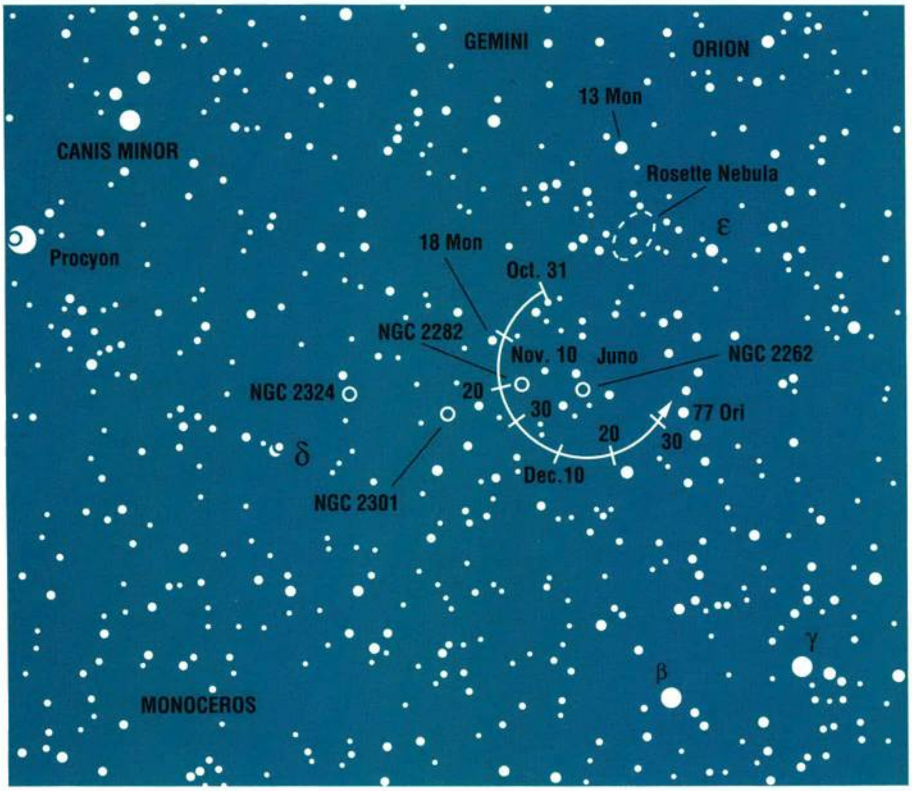
Photos by Donald C. Parker

MARS AND JUPITER are prominent this month. Mars (top) outshines the stars surrounding it in Gemini and rises late in the evening. Jupiter (in the constellation Virgo) climbs above the horizon early in the morning.

These changes are most apparent in northern mid-latitude features such as Acidalium Mare and Niliacus Lacus and in the well-known wedge-shaped equatorial feature Syrtis Major. Given the apparent size of Mars' disk now, telescopes in the 3- to 8-inch range are large enough to show this effect. Nevertheless, the Martian disk is small and will require high power to resolve subtle details. Use the highest magnification seeing conditions will allow — usually 150x for 3- to 5-inch telescopes, 250x for 6- to 8-inch ones, and 300x for those in the 10- to 12-inch range. Orange and red filters also help enhance the contrast in the dark areas. But don't expect any Martian feature to jump out at you. Being patient and persistent at the eyepiece, waiting for the seeing to briefly steady, and keeping your eye relaxed but attentive will pay off more than using generous apertures and filters.

VENUS CROWDS URANUS AND NEPTUNE

Venus is at last becoming more visible in the west after sunset, making it a good target for the telescope — sort of. Let's face it, Venus lacks the fascinating surface detail of Mars because of bright clouds. But what it lacks in surface detail it makes up for in its interesting display of phase and angular diameter changes. As November progresses, Venus becomes less full and more gibbous — round but flat on one side — while growing in apparent size — from 13.5" to nearly 16" across, about the size Mars will be this January.



THE MINOR PLANET JUNO lies in the faint constellation Monoceros near the Rosette Nebula. The asteroid glows at 8th magnitude and moves slowly relative to the background stars.

COORDINATES FOR JUNO

Date	R.A. (2000.0)	Dec.
November 2	6h44.2m	+3°38'
November 6	6h46.0m	+3°03'
November 10	6h47.2m	+2°29'
November 14	6h48.0m	+1°57'
November 18	6h48.2m	+1°27'
November 22	6h47.8m	+0°59'
November 26	6h46.8m	+0°35'
November 30	6h45.3m	+0°14'

Since July, after coming from the far side of the Sun, Venus has been trekking steadily southward and gaining altitude. All summer, it has skimmed above the western horizon, moving through Gemini, Leo, and Virgo and finally entering Scorpius by late October. It crosses into Sagittarius around mid-November. Venus moves into inferior conjunction in April 1993.

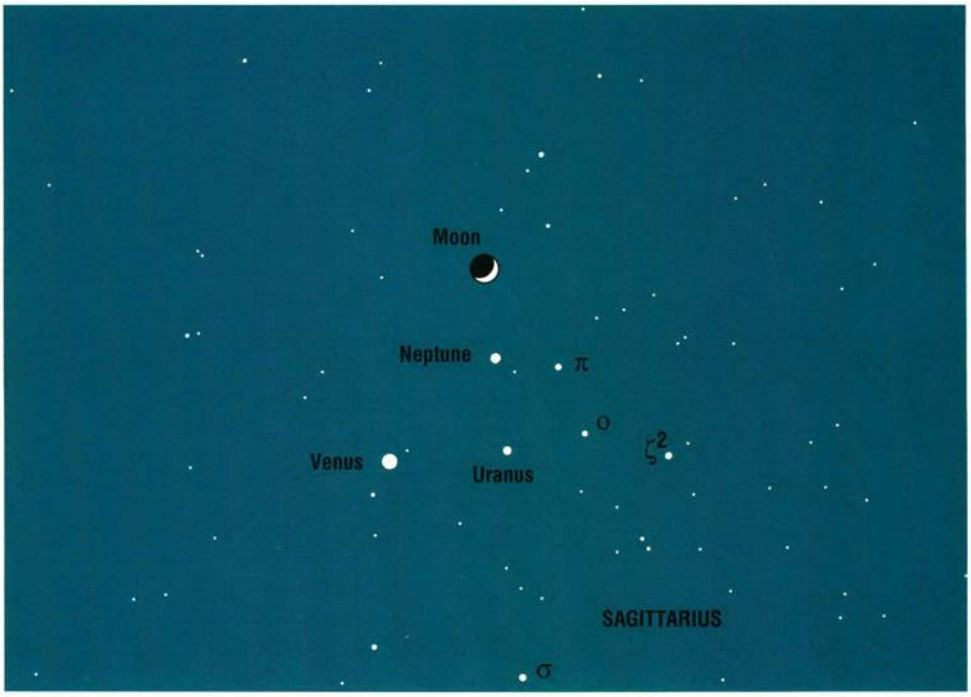
Before it does that, though, the "Evening Star" will pass near **Uranus** and **Neptune** in the latter part of November. By then, the "teapot" asterism in Sagittarius will be spout-down, and Venus will lie above the upturned handle. On the evening of November 27, Venus and the 3-day-old crescent Moon are beautifully composed in the west. Nearly sandwiched between them are Uranus and Neptune. Venus passes 1.9° south of Uranus and 3° south of Neptune. And although we're talking about only 20° or 25° of altitude, that may be enough for those of you with fairly flat, unobstructed horizons to view this conjunction. Binoculars (at least 7x50s) should enable you to see 6th-magnitude Uranus as twilight deepens into darkness. Using a telescope, see if you can detect the colors of these distant worlds: Uranus should be a tiny blue-green disk at moderate magnification and Neptune a blue-gray dot. To see Neptune as a disk, you will need good seeing conditions (doubtful at that altitude) and magnifications of at least 200x.

SATURN AT QUADRATURE

Twenty-five degrees northeast of this group shines **Saturn**, still in Capricornus and still between magnitude 0.6 and 0.7. Saturn reaches quadrature — the point at which it is 90° from the Sun with respect to Earth — the evening of November 4. Such an angle means the planet is strongly lit from the side, from our point of view. Now is a good time to power-up your telescope and see if you can detect the shadow of the ball cast across the rings behind the planet.

This phenomenon is always most pronounced at quadrature, which occurs roughly three months on either side of opposition. On the morning of

May 8, Saturn was 90° west of the Sun; thus the shadow was cast west of the ball across the planet's rings. Now that Saturn is 90° east of the Sun, the shadow falls across the rings on the eastern side of the planet. The shadow is black and deep and gives the planet a strong three-dimensional presence in the telescope. In many respects, Saturn is more dramatic at quadrature than it is at opposition for the same reason the Moon is more dramatic at quarter phase than it is at full phase: the side-lighting provided by the Sun results in more visual relief and contrast to the Saturnian system than the straight-on lighting when the planet is near opposition.



A PLANETARY PILEUP occurs on November 27 when the Moon, Venus, Uranus, and Neptune all gather in the constellation Sagittarius. Look for the group with a pair of binoculars or a telescope.

JUNO IN NOVEMBER

East of Orion, in the rich star fields of the constellation Monoceros, the minor planet **3 Juno** — one of the brightest asteroids — is beginning to brighten. For the first half of November, it shines at magnitude 8.4, increases to 8.3 and 8.2 during the third week and 8.1 by November 24. Chart 228 in *Uranometria 2000.0,* Volume I, will allow you to track this asteroid during November as it begins its retrograde loop southeast of the Rosette Nebula (NGC 2237-9) and northwest of the open cluster NGC 2301. It's a lovely region, but a bit tough if your objective is to look for an 8th-magnitude asteroid: there are dozens of other 8th-magnitude objects in the search field. But that's what makes observing Juno a challenge.

Juno's motion is rapid at the beginning and end of November. During midmonth, however, the asteroid's apparent motion per day slows as it begins looping back toward the west. Opposition occurs December 28 (peak magnitude 7.7).

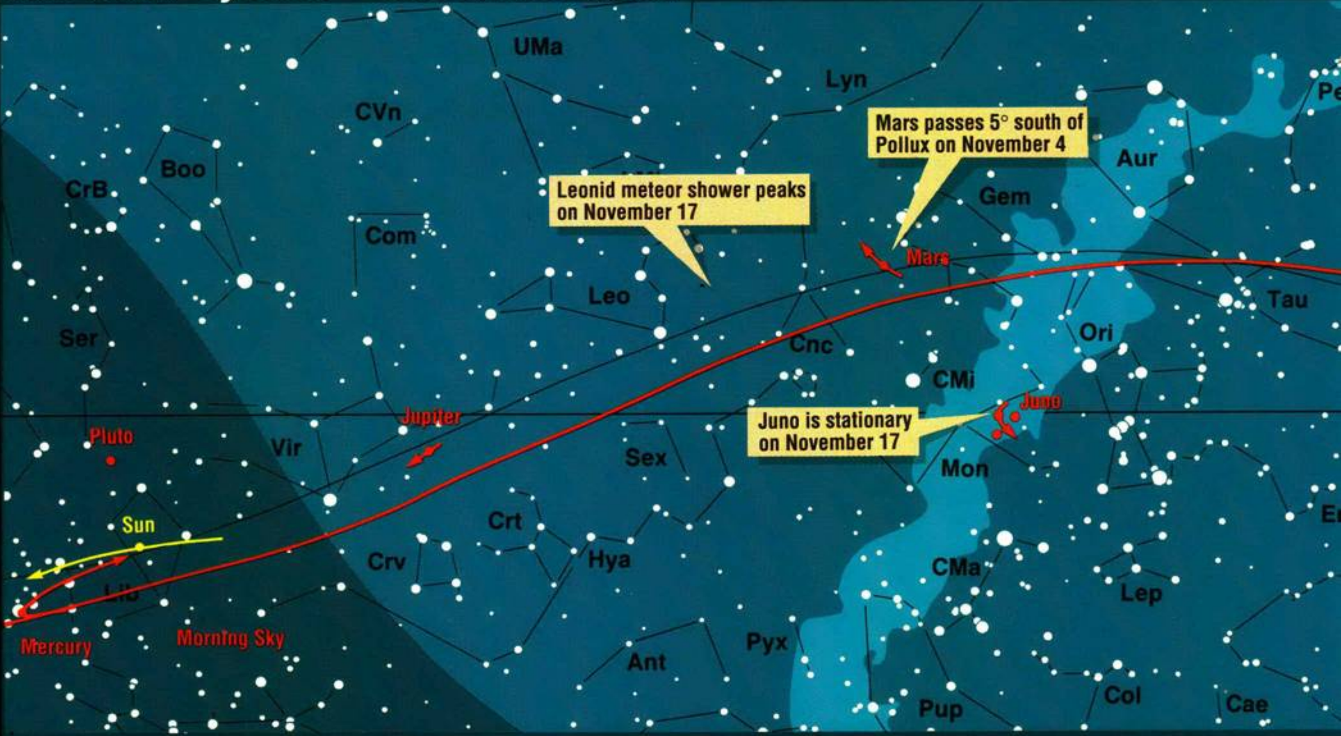
Perhaps the best time to look for Juno occurs during the period of November 10-12, when the asteroid slips just east of 18 Monocerotis, heading south. The 4th-magnitude star 18 Mon lies almost directly between Procyon in Canis Minor and Alnitak, the easternmost "belt" star in Orion. Or if you have setting circles, center on Sirius and slew northward in declination about 19 degrees.

The star 18 Mon should provide a fairly bright reference star to aid you in locating Juno. Use an eyepiece with at least a 1° true-field of view and center 18 Mon near the eastern edge of that field. On the 10th, at around midnight local time, Juno lies 8" to 9" northwest of 18 Mon; on the 11th at the same time, it is due west about the same distance; and on the 12th, it is southwest — again, about 8" or 9". Sketch the stars in the field and then check the area the following night and look for the star that has shifted position. Juno will be practically stationary in right ascension (east-west), but you should notice some motion in declination (north-south).

If you want to photograph Juno, let 18 Mon be your guiding light. Set up for prime-focus photography and guide on 18 Mon for fifteen minutes to a half hour or so. The track of the asteroid should be plain as a stubby bar of light among the stars. ☐

Jeff Kanipe is the editor of Star Date *magazine, which is published by McDonald Observatory at the University of Texas at Austin.*

The Solar System November 1992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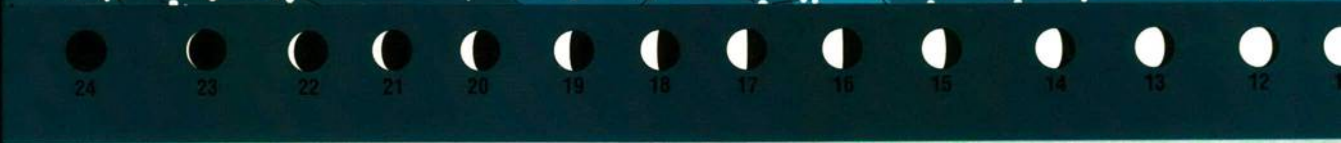
Mars passes 5° south of Pollux on November 4

Leonid meteor shower peaks on November 17

Juno is stationary on November 17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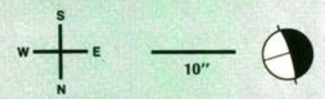
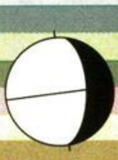
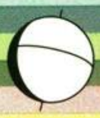


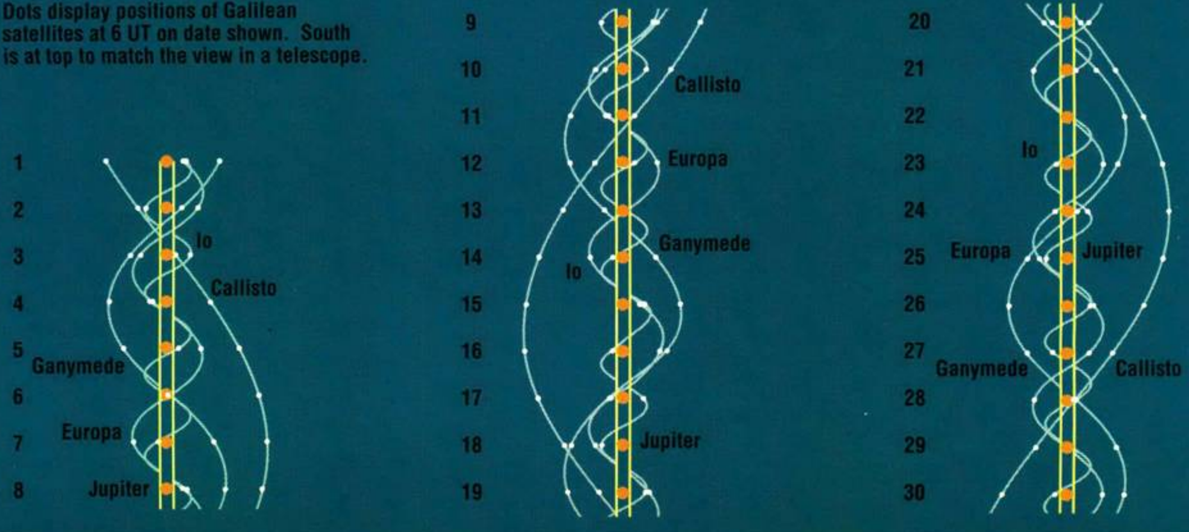


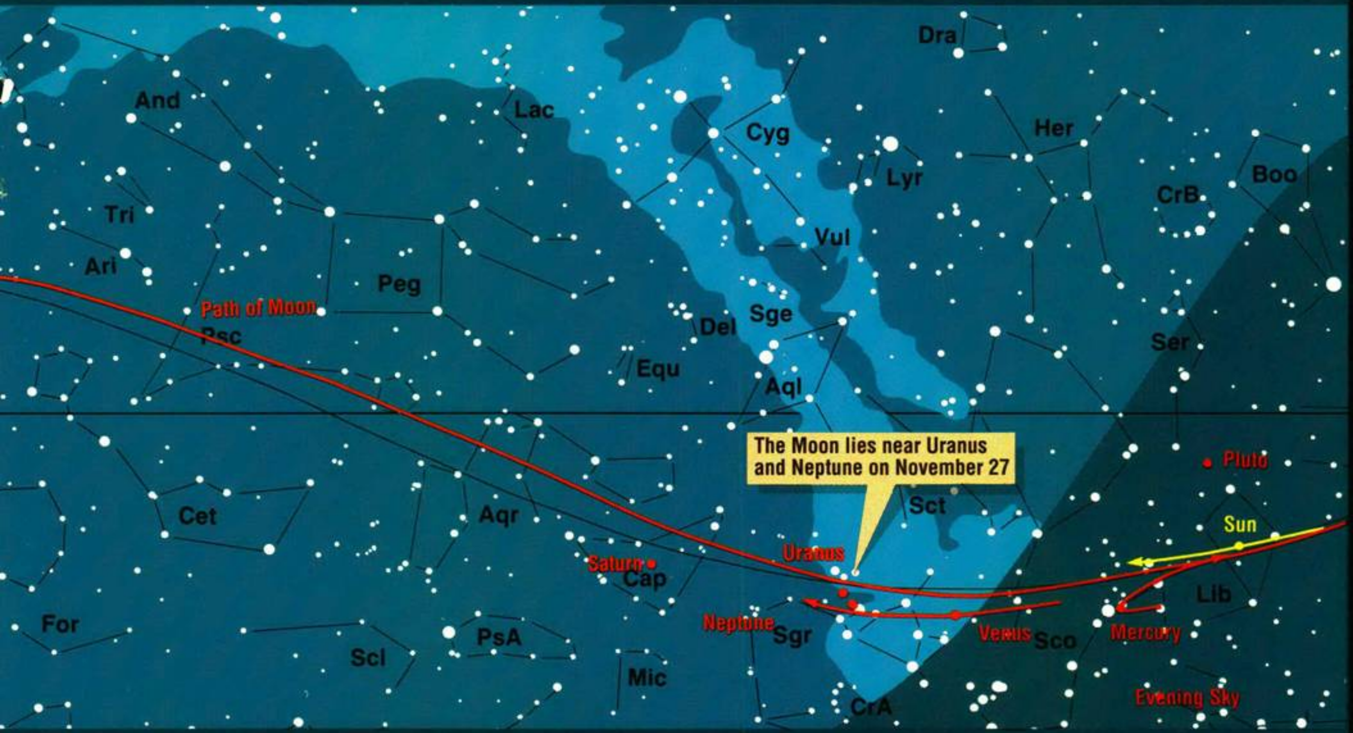


Planet	MERCURY	VENUS	MARS
Date	November 1	November 15	November 15
Magnitude	–0.1	–4.0	–0.4
Angular Size	6.7″	14.5″	11.3″
Illumination	62%	76%	91%
Distance (AU) from Earth	1.010	1.148	0.830
Distance (AU) from Sun	0.334	0.728	1.549
Right Ascension (2000.0)	15h59.1m	18h08.2m	7h55.4m
Declination (2000.0)	–23°27′	–25°30′	+22°40′

Jupiter's Moons

Dots display positions of Galilean satellites at 6 UT on date shown. South is at top to match the view in a telescope.

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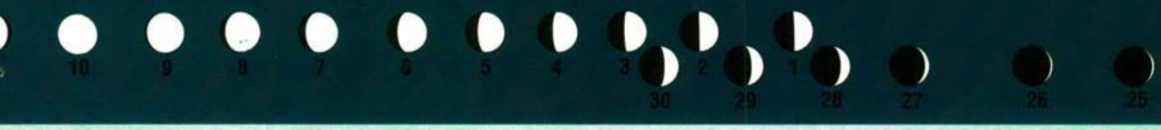
Evening Sky

The Moon lies near Uranus and Neptune on November 27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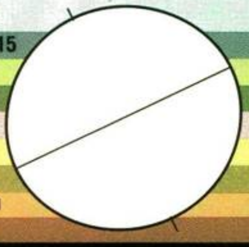
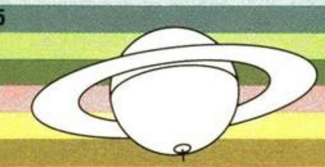
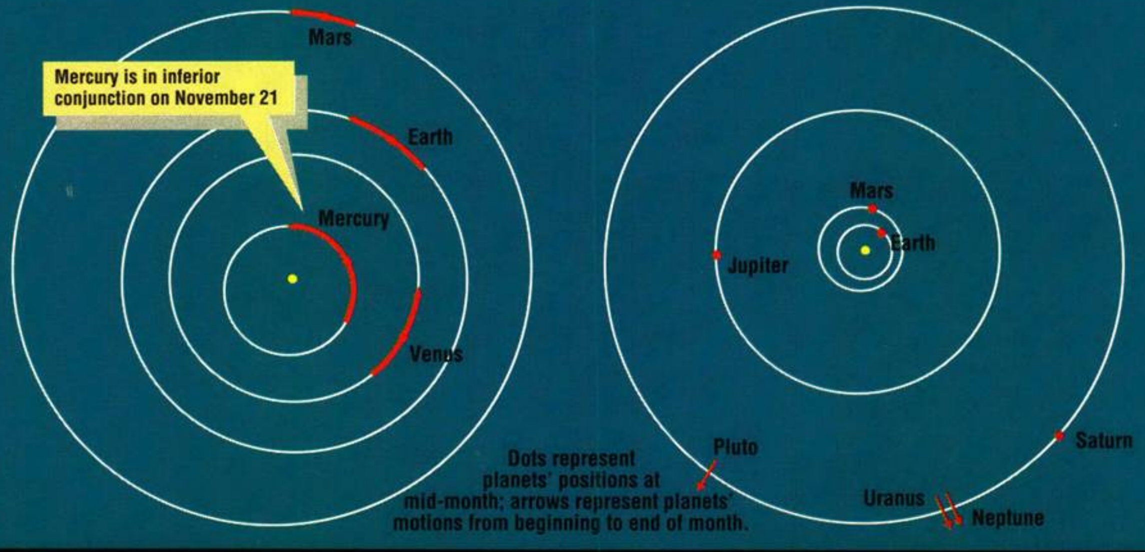




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
November 15	November 15	November 15	November 15	November 15
−1.8	0.7	5.8	8.0	13.8
32.4"	16.5"	3.5"	2.2"	0.1"
100%	100%	100%	100%	100%
6.086	10.003	20.153	29.760	30.673
5.444	9.875	19.564	30.189	29.715
12h27.9m	21h01.8m	19h06.6m	19h12.9m	15h36.5m
−1°46'	−17°59'	−22°58'	−21°41'	−4°51'

The Planets in Their Orbits


Mars
Earth
Mercury
Venus
Mars
Earth
Jupiter
Pluto
Saturn
Uranus
Neptune

Mercury is in inferior conjunction on November 21

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Build an Astrophoto Platform

An inexpensive stepper motor automatically tracks the constellations for great astrophotos.

by John Iovine

You want great photos of the constellations. But you don't have a telescope to mount your camera piggyback to prevent star trailing. What can you do? One simple solution is to build a barn-door camera mount.

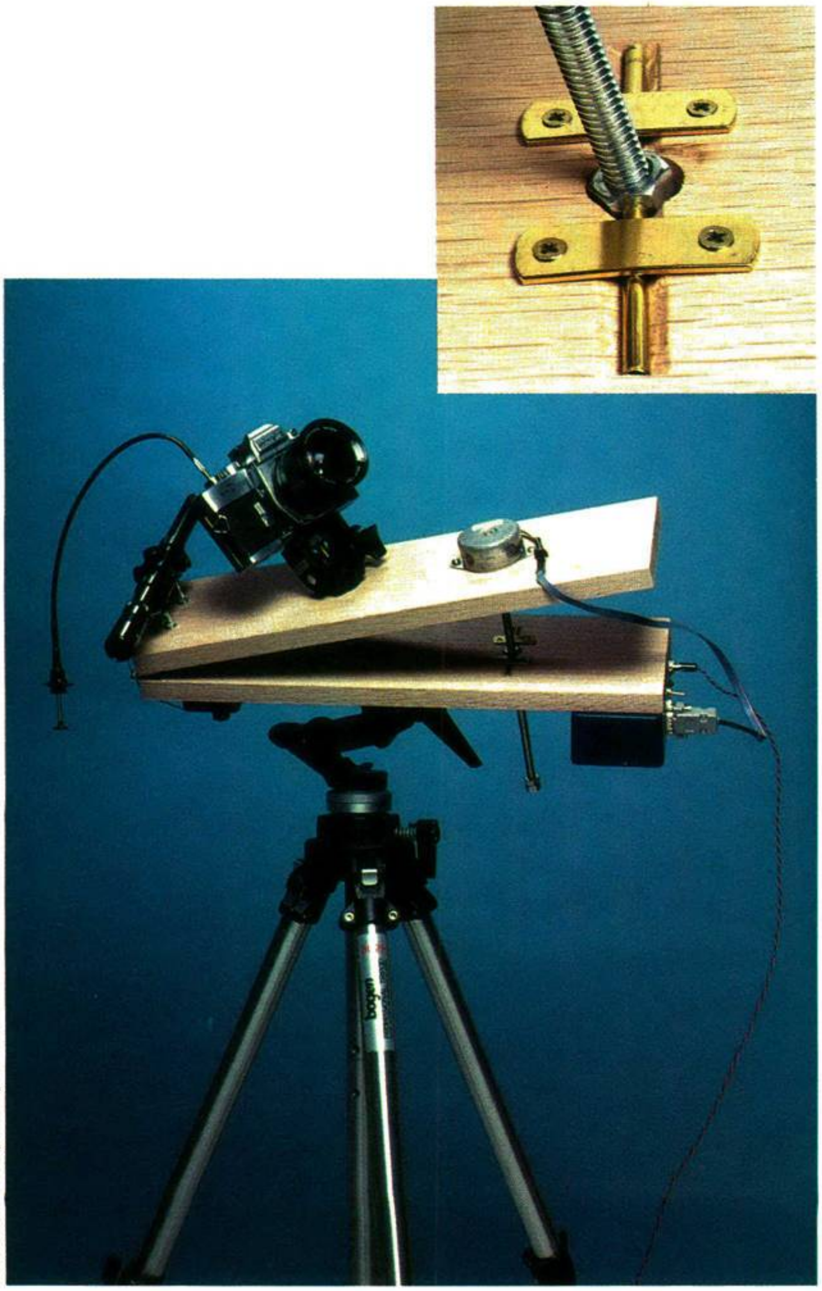
Barn-door camera platforms, so-called because they swing open like a barn door, mount on a camera tripod. A screw pushes two hinged pieces of wood apart to track a camera at Earth's rotation rate. Like a telescope's polar axis, the platform's hinge is aligned with the celestial pole to permit easy tracking.

When these simple camera mounts were first developed, they were driven by hand, but this activity quickly becomes tiresome. It is simple to add a stepper motor to the camera platform to take away this burden and automate the tracking.

In about twenty hours, you can build a barn-door tracker complete with motor drive. The tracker itself costs between $20 and $35, and the motor drive costs between $40 and $50. Complete with a small scope to help align the mount with the celestial pole, you can build the tracker for under $100.

Building a Barn Door

The three main parts of a barn-door mount are the hinge, two wood members, and a drive screw. Use a good grade of $^1/_2$-inch exterior plywood or a 1x6 piece of hardwood for wood stability. One piece of wood forms a base board that attaches to a medium- or heavy-duty



ASTRONOMY: both photos by Darla Gawelski

TRACKING THE CONSTELLATIONS is a breeze with a motorized camera platform. A gimbal-mounted drive screw (top) permits exposures as long as 30 minutes.

ASTRONOMY: Alan Dyer

NO STAR TRAILS APPEAR in this 4-minute exposure of the constellation Lyra. Alan Dyer used the camera platform described here, Konica SRV-3200 film, and a 105mm lens at f/2.5.

camera tripod and the other forms a camera board that holds the camera and motor. The boards should be about 18" long (about 16$^{1}/_{2}$" if you use a 1/4x20 drive screw).

The hinge supports the boards along one end. A wide piano hinge, two butt hinges, or a door hinge can support the weight of the platform, but be sure the hinge has little side play to prevent tracking errors. The hinge need not be mortised into the wood, but take care to install the hinge perpendicularly to the long axis of each board.

Once the hinge is in place, drill an $^{1}/_{8}$" pilot hole through both boards exactly 12$^{3}/_{4}$" from the center of the hinge pin (11$^{3}/_{8}$" for a $^{1}/_{4}$x20 drive screw). In the top, or camera, board, enlarge the hole to accommodate the motor shaft and flexible coupling (about $^{5}/_{8}$"). Enlarge the hole in the base board to $^{3}/_{4}$" to hold the gimbal-mounted drive screw.

The drive screw is an 8" length of $^{5}/_{16}$x18 threaded rod (or $^{1}/_{4}$x20 rod). A simple gimbal mount (see the inset photo on opposite page) fixes the drive screw on the base board and permits more accurate tracking. Without the gimbal, the screw's head would move along the base board as the two boards opened. The changing distance between the hinge and drive screw would introduce a tracking error into your pictures.

To build the gimbal, drill and tap two 4x40 holes along one diameter of a $^{5}/_{16}$x18 nut. (If you don't have a $^{5}/_{16}$x18 tap to chase the threads after drilling the holes, insert a disposable screw into the nut while the holes are being drilled.) Be sure these holes are aligned with one another and pass through the center of a screw threaded through the nut. Cut the heads off two 4x40 machine screws and screw into the tapped holes. The screws should not extend into the nut's threads. Cyanoacrylate glue will help hold the screws in place but be careful not to get any glue on the nut's threads.

Brass tubing about $^{1}/_{8}$" in diameter and 1$^{1}/_{2}$" long holds the 4x40 screws in V-notches cut in the base board. Be sure that these V-notches are parallel to the hinge pin. Small brass mending plates hold the brass tubes fast in the notches.

To mount the camera, secure a tripod head or ball-and-socket mount (available from your camera store) about 8" from the hinge on the camera board. Countersink any screw heads in the camera board so they don't strike the base board.

For mounting the camera platform to a tripod, install a $^{1}/_{4}$-20 T-nut (use a $^{5}/_{16}$" drill) in the base board directly below the ball-and-socket head on the camera board. The T-nut may need countersinking, depending upon the length of the screw on your tripod. The grippers on the T-nut should be on top of the base board so they pull into the wood as you tighten the tripod's screw.

With the hinge, gimbal mount, and the tripod and camera mountings installed, thread about three inches of the drive screw into the gimbal mount. Now it's time start work on the stepper motor.

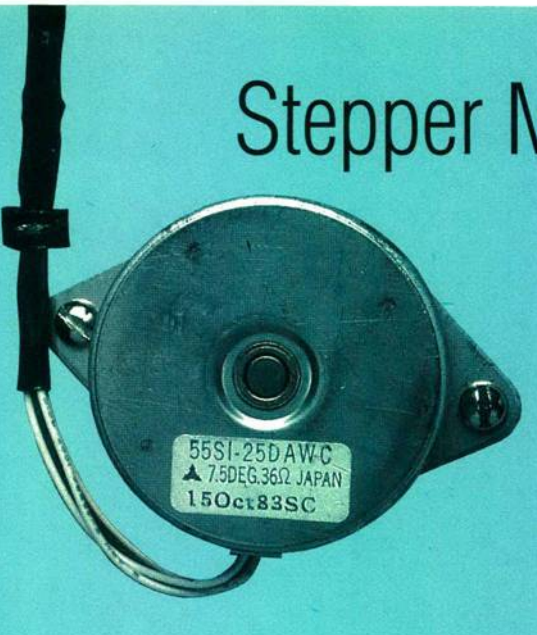
The Stepper Motor

Stepper motors are widely available as surplus motors, either new or used, from science equipment surplus stores. Look for a 12-volt (DC) unipolar motor, with four phases (coils) and a high holding torque. Such a motor should cost $10 or less.

A stepper operates by sending current through each set of motor coils in turn. When the coils receive the current, they step the motor shaft by a small amount. Typically these motors will turn 3.75, 7.5, or 15 degrees per step. A large number of degrees per step results in a jerkier motion, so 15°/step is the upper limit for tracking.

To obtain slightly better tracking performance, the stepper can use two coils at once to run in half-step mode

Stepper Motors



ASTRONOMY: Darla Gawelski

For a portable camera platform, stepper motors make more sense than DC or gearhead motors. Inexpensive DC motors aren't strong enough and most gearhead motors need 120 volts AC, which isn't available at remote observing sites. Stepper motors have high torque and their rates can be easily and precisely controlled. These motors use DC power and are readily — and cheaply — available from surplus dealers.

You'll find a wide variety of steppers available as surplus. But because they're surplus, there is usually little information provided with the motor at purchase. So it is helpful to know how to decipher the wires coming from the motor.

Usually the ad for the motor or a label on the motor will give the voltage rating and the current or resistance rating for each winding, also called a coil or phase. Be sure the motor is a unipolar motor: bipolar motors require two voltage supplies and the standard driver chips, such as the UNC-5804, can only drive unipolar steppers.

If the current rating or resistance rating is not available, you can measure it with an ohmmeter (it must measure down to 1 ohm). The maximum current that a UNC-5804 can handle is 1.5 amperes per output, so make sure the stepper doesn't require more than 1.5 amperes. If the coil current is not given, calculate it by dividing the stepper motor voltage (in volts) by the coil resistance (in ohms) to obtain the current (in amperes) required.

Four-phase steppers will have from 5 to 8 wires that connect to the coils. Variations on these are: 5 wires — a wire for one end of the coils and a common wire to all coils; 6 wires — a wire for one end of the coils and two common wires; 8 wires — a wire for each end of the coils.

Find the wires that go to the different coils. For example, measurements on a motor with 6 wires red, blue, yellow, brown, black, and white showed 36 ohms between the following wires: white to red, white to brown, black to blue, and black to yellow. The white and black wires form the common power wires to the coils. White, red, and brown form one set of coils, and black, yellow, and blue form the other set.

Now that you have identified the wires with coils, you need to discover the sequence needed to rotate the shaft. Put a pointer on the motor shaft to make any shaft movement easier to see. Connect the 2 common wires to the proper voltage. Arbitrarily select one of the other 4 wires (say, brown) to be phase "A." Touch the battery ground wire to this wire to establish the shaft's location.

You want to find the sequence that turns the shaft clockwise. So select another wire and touch it to the battery ground. If the shaft didn't turn clockwise, touch the phase A wire to ground and try another wire. The second step is phase B and so on. (For my motor, the sequence was brown, blue, red, and yellow.)

Connect the first coil set (phases A and C) common (white) to pin 2 of the UNC-5804 chip and the other set's (phases B and D) common to pin 7. Connect phase A to pin 1, phase B to pin 8, phase C to pin 3, and phase D to pin 6. — *Jack Dowell*

— that's why you need a four-phase motor. Running the stepper in half- or full-step mode requires a controller chip (UNC-5804). (If you can't obtain a stepper or the controller chip locally, contact Images Company North, P. O. Box 140742, Staten Island, NY 10314-0024; phone (718) 698-8305. They sell the motor and chip for $10 each, plus a shipping fee of $5.) See discussion at left to determine your motor's wiring and how to connect it to the controller chip.

The circuit shown on page 63 requires 12 volts, from a car, lantern, or rechargeable battery. Build the circuit on perfboard and use sockets for integrated circuits U1 and U2. Wirewrapping works fine, although you may wish to use heavier wire and solder the motor connections.

Besides the controller chip, the other crucial part of the circuit is the timer, which tells the controller how often to step the motor. The resistors (R1 through R4) control the stepping rate and may have to be reset for your motor. The values shown here are for a 3.75°/step motor in half-step mode. (Pins 9 and 10 on U2, the controller chip, are set for half-step mode.)

The circuit should drive the motor and drive screw so the screw turns exactly once per minute (1 rpm). Make a mark on the drive screw — or a pointer — and time your motor's rate. If it's too fast, increase the resistance of the variable resistor (R3). If it's too slow, decrease R3.

For a 7.5°/step motor in half-step mode, change R1 plus R2 to 270 kilohms and R4 to 330 kΩ. For a 15°/step motor, change R1 plus R2 to 660 kΩ and R4 to 470 kΩ. It's a good idea to install the resistors in such a way that you may easily replace them if you have to change values.

Switch S2 changes the direction of the drive screw motion so you can reset the screw for another exposure. Switch S1 changes the motor speed so the platform can be reset quickly.

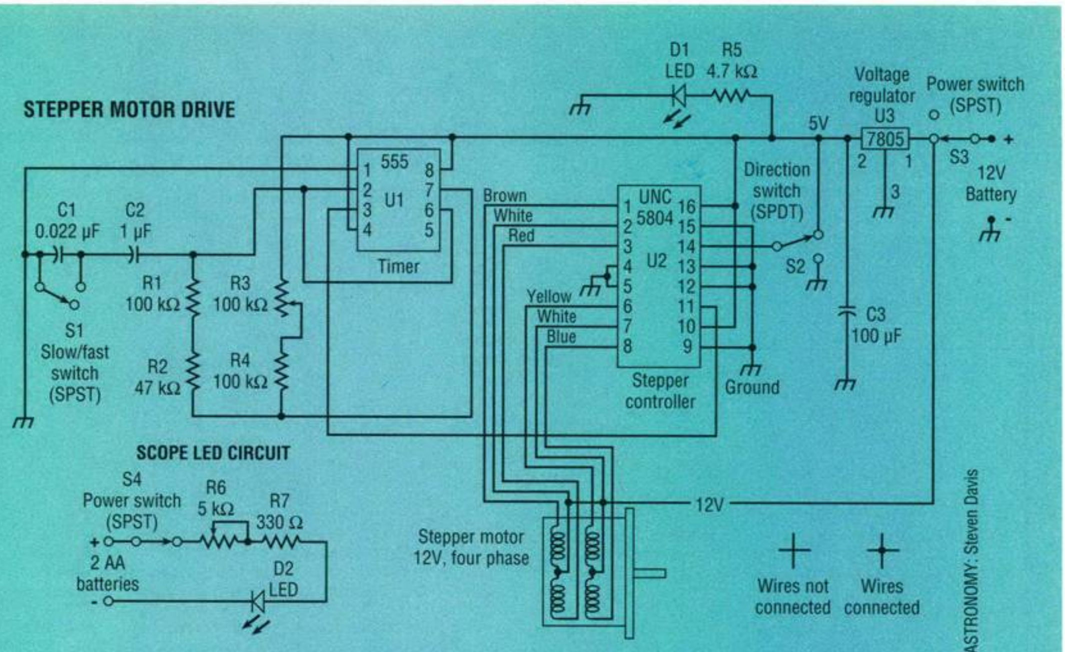
With the circuit assembled and tested, install the motor on the camera board and connect it to the drive screw with a flexible coupling. Commercial couplers are hard to find and can be expensive. A simple alternative is to use 2" of air hose (available from a hardware store) — use 3/16" inner-diameter hose for a 1/4" motor shaft.

Now comes the real testing of the drive. Put the platform on your tripod and mount your camera along with the heaviest lens you expect to use. Turn on the motor drive and check that the drive screw still turns at 1 rpm. Check out the fast motor speed also — up and down.

PARTS LIST

Astrophoto platform:

2 1"x6"x18" hardwood boards
1 2" wide piano hinge (cut to length)
1 5/16x18 threaded rod, 12" long
1 5/16 nut
2 4x40 machine screws, 1" long
2 1/8" inner diameter brass tubing, 2" long
2 1 1/2"-long mending plates
1 flexible motor coupling or 3/16" air hose
1 camera tripod head
2 1/4x20 T-nut
wood screws to attach hinge, motor, mending plates, and electronics boxes



STEPPER MOTOR DRIVE
C1 0.022 µF
C2 1 µF
S1 Slow/fast switch (SPST)
R1 100 kΩ
R2 47 kΩ
R3 100 kΩ
R4 100 kΩ
1 2 3 4 555 U1 8 7 6 5
Timer
D1 LED
R5 4.7 kΩ
Voltage regulator U3 7805
2 1 3
Power switch (SPST)
S3
5V
+
12V Battery
-
Brown
White
Red
Yellow
White
Blue
UNC 5804
U2
1 2 3 4 5 6 7 8
16 15 14 13 12 11 10 9
Stepper controller
Direction switch (SPDT)
S2
C3 100 µF
Ground
12V
Stepper motor 12V, four phase
SCOPE LED CIRCUIT
S4 Power switch (SPST)
R6 5 kΩ
R7 330 Ω
+
2 AA batteries
-
D2 LED
Wires not connected
Wires connected

ASTRONOMY: Steven Davis

Stepper controller

	Radio Shack Part number
Integrated circuits	
U1 555 timer	276-1723
U2 UNC-5804 stepper controller	
U3 7805 voltage regulator	276-1770
Resistors	
R1, R4 100 kilohms (kΩ)	271-1347
R2 47 kΩ	271-1342
R5 4.7 kΩ	271-1330
Variable resistors	
R3 100 kΩ	271-284
Capacitors	
C1 0.022 microfarad (µF)	272-1066
C2 1 µF	272-996
C3 100 µF	272-1016

	Radio Shack Part number
Switches	
S1, S3 SPST	275-634
S2 SPDT	275-635
Miscellaneous	
D1 LED (red)	276-041
Stepper motor, 12 volt (V)	
project box (optional)	270-223
perfboard	276-1395
two 16 pin sockets	276-1994
DC power jack (optional)	274-1563
DC power plug (optional)	274-1569
12 V battery	
wire	

Optional

Polaris spotting scope

1 4x riflescope (available from K-mart)
1 1/2" x 1/16" x 4" brass strip
2 8x32 machine screws, 2 1/2" long
8 #8 washers
4 #8 nuts
4 #8 lock washers
2 #8 wing nuts

Scope LED circuit

R6 5 kΩ variable resistor	271-1714
R7 330 Ω resistor	271-1315
D2 LED (red)	276-041
S4 SPST switch	275-634
project box (optional)	270-220
2 AA battery holders	270-401
2 AA batteries	

If the motor doesn't like turning — it just wiggles back-and-forth in one place — all may not be lost. Try putting a finger under the camera board and push up slightly. If the motor starts turning properly, a light spring placed between the two boards may aid the motor sufficiently. If your motor is powerful enough, a weak rubber band wrapped around the two boards reduces backlash and prevents additional tracking errors.

Using Your Sky Tracker

For the platform to track the constellations, you must align the hinge pin with the celestial pole (Polaris is close enough). You can polar align the tracker by looking through a 1/4" tube, mounted parallel with the hinge pin. A 6x30 finderscope or an inexpensive riflescope can help you obtain even more accuracy in tracking. (An LED backlight helps you see the scope's reticle — see the circuit above.)

Turn the power switch to on, the slow/fast switch to slow, and the direction switch so the platform will follow the constellations in their paths from east to west. The tracker's screw length should let you operate for about two hours before you have to reset the screw. But this simple design accumulates tracking errors after about 30 minutes, so use shorter exposures. (For some help on how to take great astrophotos, see "Capture a Constellation" in this issue.)

A stepper motor may not make taking astrophotos flawless, but it will allow those of us without telescopes to track the constellations, removing annoying star trails from our photos. And it's relatively portable too. The drive screw can be removed and the whole platform loaded in a suitcase for a trip. Take a weekend and build yourself one of these motor-driven camera platforms. You won't be sorry you did. ☐

John Iovine is an amateur astronomer living in Staten Island, where he fights the Big Apple's light pollution to get astrophotos.

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See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive."

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Model 152 ED 6'' f/9 Apochromat & mount (add $185 P&S)	**$3995**
Model 178 ED 7'' f/9 Apochromat & mount (add $215 P&S)	**$4995**
Photographic field corrector lens (specify telescope model)	**$250**

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8,000 Object CNGC Library	**$99**
Polar alignment finder	**$99**
Optional optical encoders for #1697 drive	**$299**

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8'' LX200
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10'' LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2595**
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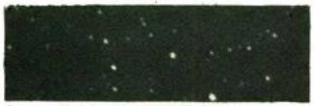

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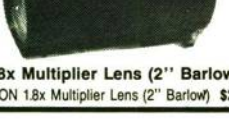
2'' DELUXE BARLOW



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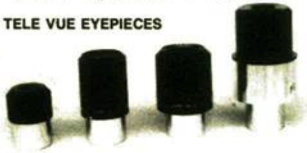

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ASTRONOMY February 1991

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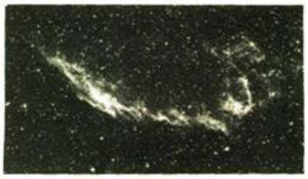
Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



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Astronomy, Feb. 1991

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U.S. Patent 4,473,636

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U.S. Patent 4,448,500

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Fuji HG400 fine grain color neg.	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
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CAPTURE A CONSTELLATION

Create your own photographic star atlas. All it takes is the simplest equipment and the fastest film.

by Mark J. Coco

FOR THE BIG DIPPER, Edmund Swansborough used simple equipment: a camera on a tripod and a 75-second exposure on ISO 100 film with a 28mm lens set to f/2.

It's late autumn and the winter constellations are beginning to make their appearance in the east shortly after dark. The constellation Orion dominates the scene, its bright stars forming a pattern that clearly resembles the mythological figure they represent. You want to photograph it, but you don't have a telescope. Well, don't let that get you down — you don't need one to get started photographing the heavens.

You can photograph the constellations with equipment you may already own. All you need is a camera, lens, tripod, and some fast film. You can concentrate on the bright constellations such as Orion or, for a rewarding year-long project, you can produce your own photographic sky atlas by capturing each constellation.

Cameras for Constellations

First you need a camera, but not just any camera. You need one with a "B" or "Bulb" setting that allows you to lock open the shutter for time exposures. This rules out most point-and-shoot cameras. The best choice is a 35mm-format single-lens reflex (or SLR) camera.

Second, the shutter should not be electronically controlled, at least while using the B setting. Many of today's cameras use battery power to keep the shutter open during time exposures. Once the batteries are drained, usually after a few minutes, the shutter closes whether you were finished with the exposure or not. Look for a camera that has a mechanical shutter that does not require battery power when operating at the B setting.

ASTRONOMY: All equipment photos this story Darla Gawelski

AN EASY PORTRAIT, Orion entangled in trees. Fred Hafeli used a medium-format camera guided on a small telescope for his 5-minute exposure; a home-built camera tracker produces similar results.

The camera should also have interchangeable lenses. A wide-angle lens such as a 28mm will take in over 60° of sky, enough to frame some sprawling constellations such as Pisces and Cetus. A short telephoto such as a 135mm has a 15°-wide field, suitable for framing smaller constellations such as Lyra and Triangulum. By far the most useful lens for constellation portraits is a normal 50mm. Its 40°-wide field is ideal for containing most constellations. In fact, if you embark on a constellation atlas project, you might want to use a 50mm lens exclusively so that every constellation appears the same size on each frame. The big constellations would need two or three frames to capture their entire extent.

You will also need a rigid tripod. Avoid the lightest-weight models — they will prove too flimsy, especially when extended to a comfortable height. The final piece of hardware you need is a cable release

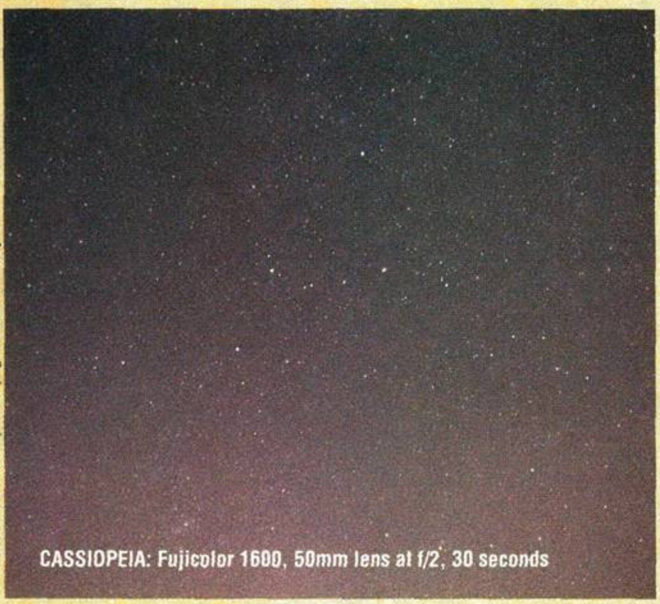
CAMERA ON TRIPOD

PINPOINT STARS

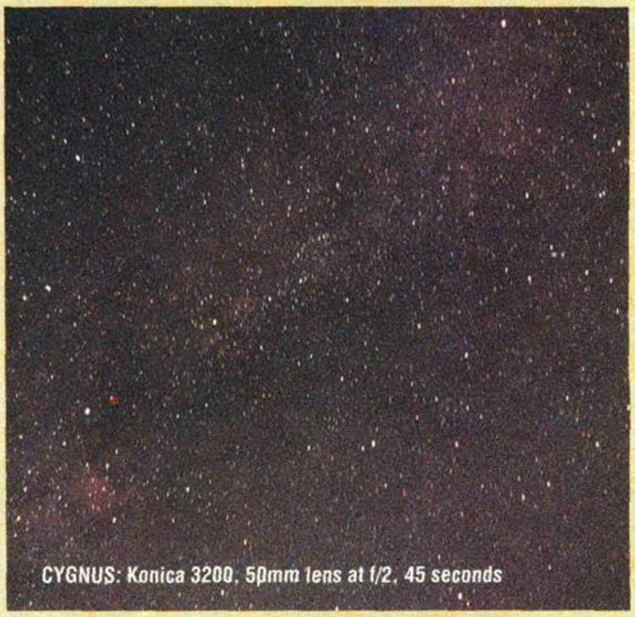
To keep stars from trailing when using a fixed camera, be sure to keep your exposure times shorter than these upper limits. Because you have a limited exposure time with a fixed camera, use a fast ISO 800 to 3200 film to capture as many stars as possible during that exposure.

Lens Focal Length	Celestial Equator	Approx. 45° Declination	Celestial Poles
28mm	25 sec.	40 sec.	90 sec.
50mm	12 sec.	20 sec.	45 sec.
135mm	5 sec.	7 sec.	16 sec.

ASTRONOMY: All astrophotos pages 68-69 Alan Dyer



CASSIOPEIA: Fujicolor 1600, 50mm lens at f/2, 30 seconds



CYGNUS: Konica 3200, 50mm lens at f/2, 45 seconds

IT'S A SNAP to capture constellations and even star clouds in the Milky Way, all with no more than a camera on a tripod. The secret is to use ultra-fast films such as the Konica 3200 used here.

with a locking function to hold the shutter open.

Fast Film Finalists

The secret to successful constellation shots is fast film. You can use ISO 100 to 400 speed film but you'll record the most stars in a given exposure time by using a film with a speed of at least ISO 800. If you like to shoot slide film, good choices include Ektachrome P800/1600, Fujichrome P1600D, Agfachrome 1000, ScotchChrome 1000, and ScotchChrome 400 push-processed to 800 or even to 1600. One word of caution when using color slide film: because the background sky is dark, the processor can have a tough time determining where each frame starts and ends. You might find that they have sliced your constellation shots right down the middle. Ask that your constellation roll be developed only and not cut. You will then need to cut and mount the slides yourself. Or shoot one or two normal daylight scenes at the beginning and end of each roll to guide the processor when cutting the slides.

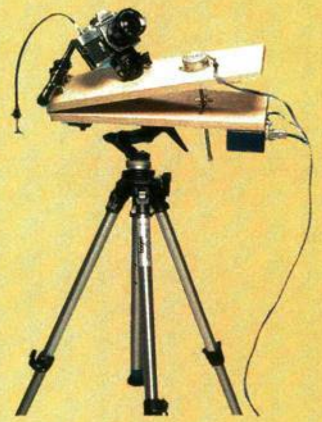
If you prefer color prints, you have some outstanding films to select from. Ektar 1000, Fujicolor 1600, and the speed champ, Konica SR-G 3200, provide high sensitivity with minimal film grain for their speed. The cautionary word with print films is that the processor may not see anything on the negative and, as a result, not print any pictures. If they do print the pictures, the sky could turn out looking like daytime. You may have to tell the processor to purposely print for a dark sky, something not usually done with normal snapshots.

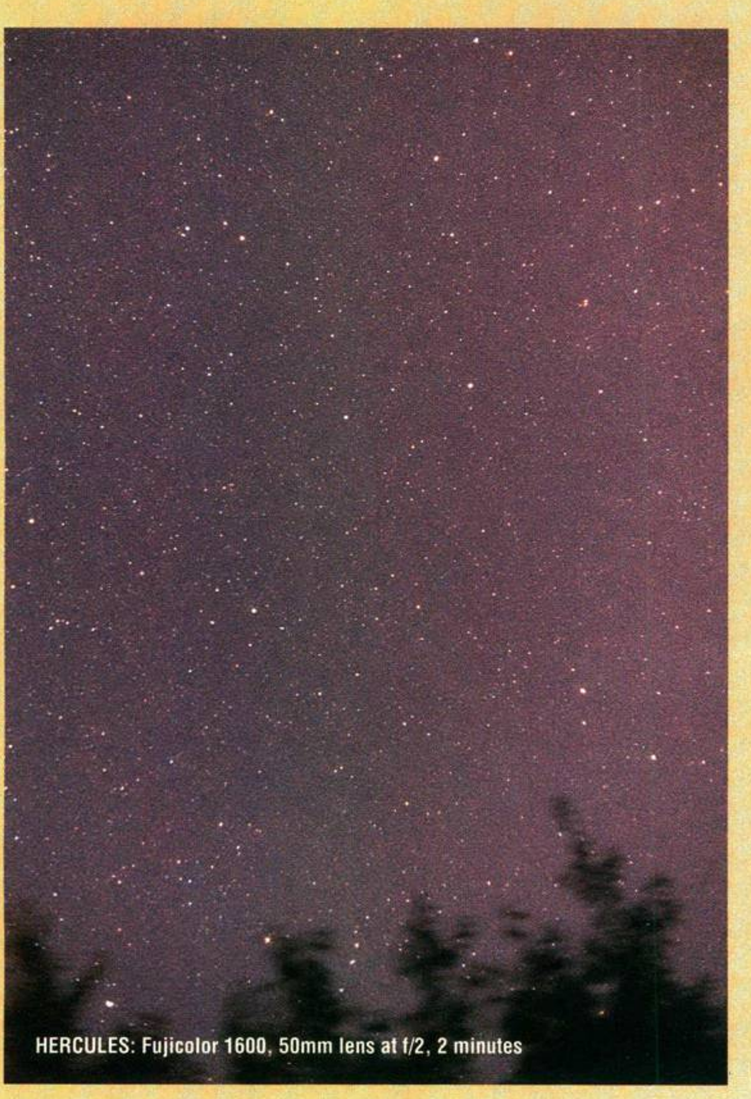
If black-and-white film is your choice, use Kodak's T-Max P3200. It has an excellent combination of speed and fine grain.

Shutter Speed Summary

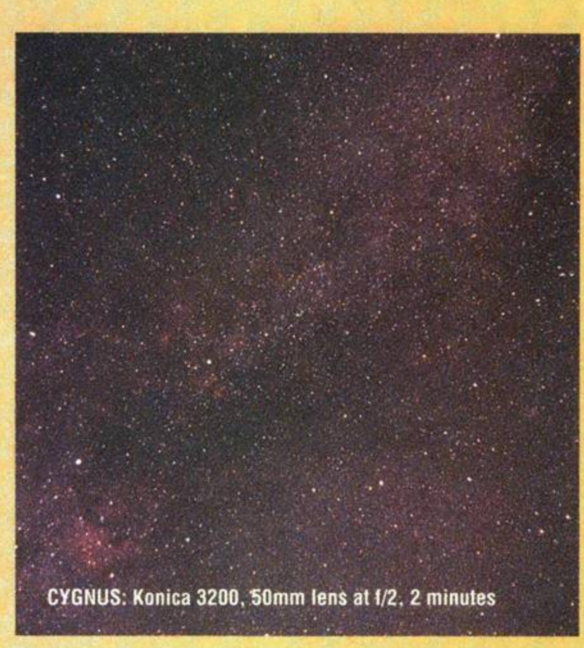
There is a limit to your exposure time if you want to keep the star images round. If you expose too long, the stars become streaked, a characteristic caused by the Earth's rotation. How long you can expose before star trailing shows up depends on what part of the sky you are photographing and the focal length of the lens you are using. To determine the maximum exposure without elongated stars, use the following formula:

CAMERA ON TRACKER





HERCULES: Fujicolor 1600, 50mm lens at f/2, 2 minutes



CYGNUS: Konica 3200, 50mm lens at f/2, 2 minutes

A SIMPLE TRACKING PLATFORM such as the barn-door tracker allows a camera to follow objects as they move across the sky, permitting exposures that record faint stars and wispy nebulosity not visible to the naked eye.

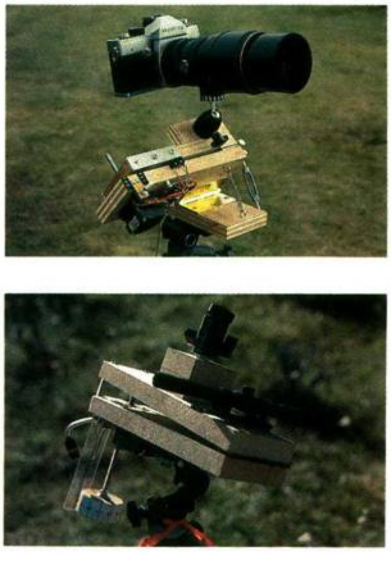
$$\text{Time (in seconds)} = \frac{1000}{\text{F x Cosine d}}$$

F is the focal length of the lens and d is the declination of the sky area you are photographing. For medium-format cameras the formula is:

$$\text{Time (in seconds)} = \frac{2000}{\text{F x Cosine d}}$$

Your exposures near the celestial poles (90° declination) can be longer than those near the celestial equator (0° declination) because the distance the stars move across the film in a given time is much smaller for stars near the poles. If you don't have a calculator with trigonometric functions, see the table for specific recommendations.

To take your constellation portrait, focus the lens to infinity. Initially, set the f/ratio to its lowest setting — it might be f/2 or f/1.4. Take a series of different exposures. Also try stopping the lens down one and two f/stops. You may find that you record just as many stars at f/2 as you do at f/1.4 and that the stars will look smaller. When used "wide open" most lenses exhibit optical aberrations that distort stars into large blobs or seagull-shaped images. It may take a little trial-and-error to determine the best exposure and aperture combination for your lens and film.



HOMEMADE CAMERA TRACKERS can vary in details but all work on the principle of two hinged boards pivoting around an axis aimed at the celestial pole.

A PERSONAL STAR ATLAS

It is late in the evening and I am searching for the globular cluster M22 in Sagittarius. It shouldn't be too hard to locate because M22 is bright and Sagittarius is an easy constellation to find. Earlier tonight, the weatherman called for snow, and he was right. It is starting to snow pretty hard now. Eureka, there it is — M22, about 2° northeast of Lambda Sagittarii. Now I can quit for the evening.

Wait a minute! Looking for a summer constellation during a snowstorm? Actually I was looking at a photograph of the night sky I had taken last summer. I have found that observing the night sky via photography is an exciting and rewarding way to study the stars. I clearly remember the first time I found NGC 2237-9, the Rosette Nebula, in a photo. It was a barely visible pink circle, but to me it looked better than Palomar's finest.

The beauty of photo-astronomy is simplicity. All you need is a camera, tripod, and cable release. Using ISO 1600 color print film I've found that 25-second exposures reveal 7th-magnitude stars, so many in fact that I soon found that it's important to log each picture I take. I record the frame number, the vertical or horizontal format, and a description of the area of the sky. It makes later identification easier.

I've also found that when I take my film to a one-hour photo shop it's usually necessary to talk to the printing machine operator. I tell the operator that the negatives contain pictures of stars and to adjust the printing exposure accordingly. The operator should also print the pictures in the same order that they were exposed and not mix up the prints. This facilitates frame identification later on. After I get the prints home and have written all of the identifying information on them, the real fun begins — searching the heavens.

I use the atlas charts in the Peterson *Field Guide to the Stars and Planets* as identification aids. Actually I use the guide backwards — I first choose a chart in the book that has some interesting objects in it and then try to find them in one of my pictures. The atlas charts in the Peterson *Field Guide* are roughly the same scale as my prints, which makes star hopping easier.

For me, photo-astronomy is a low-cost alternative to the high-tech race for bigger and better telescopes. Photographing the sky and then exploring the photos has introduced me to many celestial wonders that I can return to easily and share with others. — *John E. Horne*

CANIS MAJOR ROMPS above the southern horizon in Paul Shulins' portrait of this winter constellation. Shulins used a camera tracker and a 12-minute exposure on Ektachrome 200 film with a 50mm lens set to f/4 to ensure sharp images.

Keep on Tracking

Using a fixed camera, fast film, and exposures of only 30 seconds, you'll be able to pick up stars fainter than you can see with your unaided eye. To record even fainter stars you need to use exposures of several minutes. To prevent the stars from trailing one inexpensive technique is to use a device called a camera tracker. You can buy one commercially but one design, the "barn-door" tracker, is easy to build yourself. To learn how, turn to page 60.

A barn-door tracker consists of a pair of hinged boards. The camera attaches to the top board with some type of tripod head such as a ball-head mount. The hinge joining the

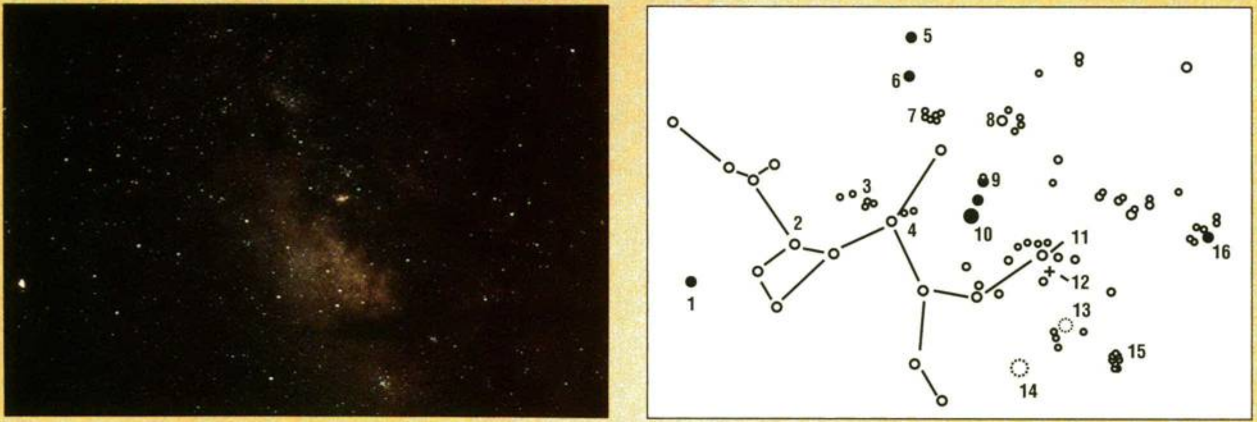


Photo and map by John E. Horne

IN HIS STAR ATLAS, Horne pastes each photo onto a page and accompanies it with a hand-drawn map (right) identifying the deep-sky objects he's recorded. For example, this 25-second exposure of the Sagittarius region reveals the following celestial treasures:

A STAR ATLAS SAMPLER

1. **Mars**
2. **Sagittarius itself**
3. **Globular cluster M22**
4. **Globular cluster M28**
5. **M16, the Eagle Nebula**
6. **M17, the Swan Nebula**
7. **Star cloud M24**
8. **Open cluster M23**
9. **M20, the Trifid Nebula**
10. **M8, the Lagoon Nebula**
11. **χ Sgr, a Cepheid variable star**
12. **The direction of the center of the Galaxy**
13. **Open cluster M6**
14. **Open cluster M7**
15. **Emission nebula NGC 6357**
16. **Globular cluster M19**

boards is pointed at the celestial pole (near the North Star for Northern Hemisphere astronomers), the point around which all the stars appear to revolve. As the top board of the tracker pivots, it allows its camera payload to follow the stars as they arc across the sky, keeping the stars pinpoints on the film. No-frills trackers can be hand-driven (see "A Portable Photographic Platform," July 1987 ASTRONOMY) but the design in this issue uses a stepper motor for hands-off tracking.

To use a tracker you begin by polar aligning the mount. A small finder or pointer attached to the top board helps you aim the hinges at the pole. Once aligned, you don't move the tracker — you use the ball head to aim the camera and to frame your constellation. Before beginning an exposure, you need to wind back the tracker mechanism so that the boards are closed. During the exposure, the turning of the long bolt between the boards will slowly open the boards and provide the tracking motion.

Because the camera is now following the stars, your exposures can run much longer without producing streaked images. You can also try zooming in on small constellations, interesting starfields, and large regions of nebulosity by using short telephoto lenses (under 200mm focal length). Or you can switch to a wide-angle lens for sweeping vistas of the Milky Way.

With ISO 800 to 3200 film and with your lens set at f/2 or f/2.8, start with a one-minute exposure and go all the way to five minutes. With films in the ISO 400 range, you can expose longer than five minutes but you may have trouble keeping the star images round (especially when using a telephoto lens) because of inaccurate polar alignment and imperfections in the tracking motor. Keep in mind that barn-door trackers are designed for relatively short exposures — you shouldn't go over 15 minutes.

Collecting Constellations

Whether you use a fixed tripod or a barn-door tracker, you'll get the best results by photographing from a dark-sky site. You can capture the brighter constellations from urban areas, but the bright sky background will wash out the faint stars.

As a final tip, be sure to keep records of each shot, or you'll almost certainly end up with mystery constellations you won't be able to identify!

As you can see, capturing the constellations takes a minimal investment in equipment. However, creating your own constellation atlas will require a modest investment in time. It may take you a year to cover the sky. But during that year you will have had the rewarding experience of learning the sky in a way few other backyard astronomy projects can accomplish. ☐

Mark J. Coco is a technical writer and amateur astronomer living in southern California.

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Refractor (SP-C102)	$895
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C4 5	$398
SPC6	$718
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Vixen 4 1/4"EQ Reflector	$289
Vixen 80mm Refractor	$375
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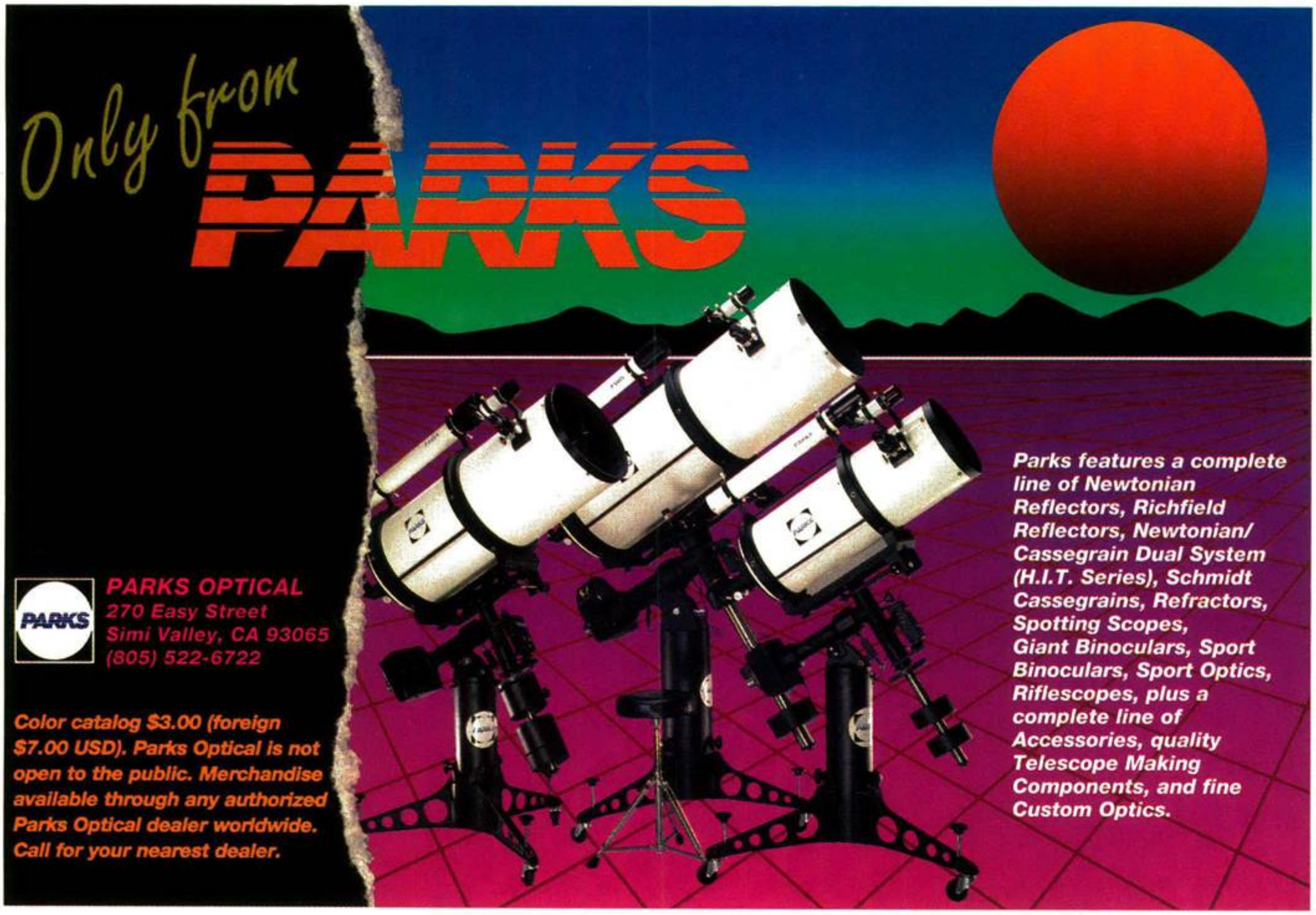

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OBSERVING THE

The Red Planet will be big and bright this winter — a perfect time to brave the cold and view our planetary neighbor.

by Edward F. Albin

Imagine seeing the most splendid planetary features in the solar system. Delight as you gaze through your telescope's eyepiece upon huge polar ice caps, giant impact basins, and fabulous volcanoes. No, this isn't the Moon. These wonders lie on the ruddy surface of Mars.

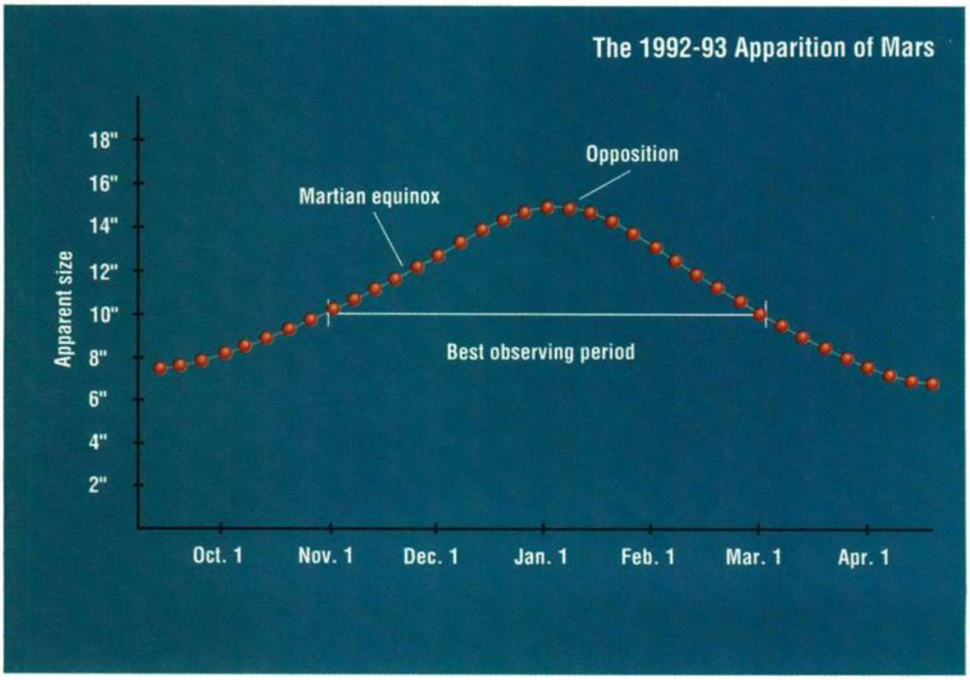
Now don't expect to see these features in sharp relief. You'll witness a pattern of light and dark markings called albedo features that coincide with the physical locations of the geologic features seen close up by the successful Mariner and Viking space probes of the 1970s. But if you come prepared with a good telescope and a detailed map of Mars, you'll be able to locate many of these albedo features for yourself.

It's been a bit over two years since planetary observers have had the opportunity to get a good look at the Red Planet. Now Mars is approaching its early January opposition and growing larger in the sky — the perfect time to get out and observe the myriad features of the Martian surface. As at the November 1990 opposition, Mars will be favorably placed this winter, high in the sky for stargazers living in the Northern Hemisphere.

Four Months of Viewing

Mars has spent all of 1992 pulling closer to Earth. Early in the year its progress was slow, and it remained an inconspicuous point of light in the morning sky. But in the last few months, the Red Planet has picked up the pace, becoming brighter, growing larger in a telescope's eyepiece, and rising before midnight.

For telescopic observers of the planet, late October marks an important milestone. That's when Mars reaches 10" in apparent diameter, a size large enough to reveal quite a bit of surface detail in a good 3-inch or larger telescope. A telescopic view of the Red Planet in late October will also show you a distinct phase effect — only 89 percent of the planet's lit hemisphere faces Earth, so Mars looks like a miniature gibbous Moon.



ASTRONOMY: Phil Kirchmeier

The pace of change quickens as Mars approaches its January 1993 opposition. On November 1, Mars appears 10.1" across, shines at magnitude –0.1, and rises before 10 p.m. local time. By December 1, the Red Planet has grown to an apparent diameter of 12.8", brightened to magnitude –0.8, and rises around 8 p.m. local time.

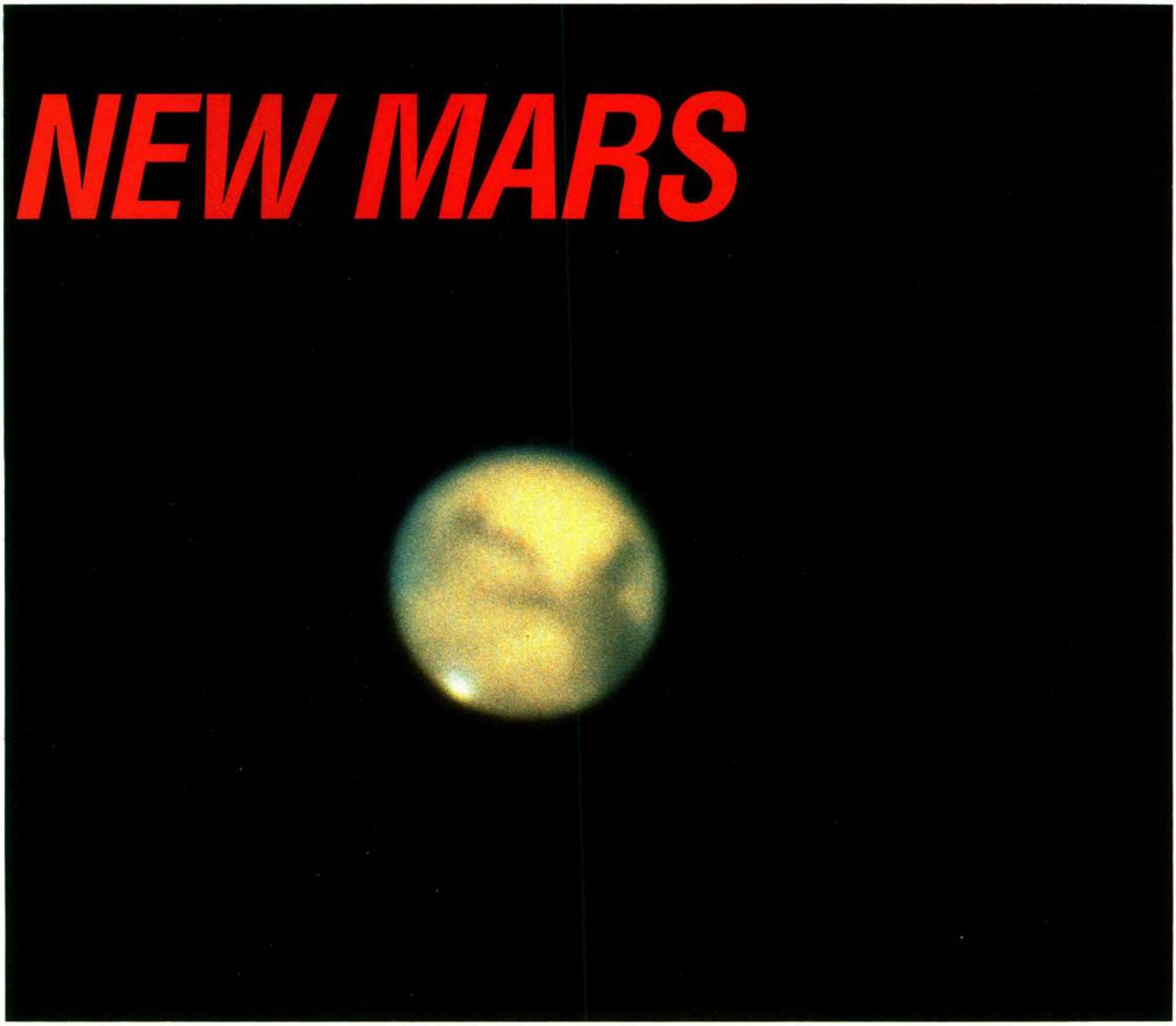
Mars is at its best during the last half of December and first half of January. It appears largest, and thus offers the best views through a telescope, at its closest approach on the evening of January 3. That night Mars lies 58 million miles (94 million kilometers) from Earth and its disk appears 15.0" across.

Four days later, the Red Planet reaches opposition, when it appears opposite the Sun in our sky. It then rises at sunset, is highest in the southern sky at midnight, and sets at sunrise. Mars is also brightest on the night of opposition, glowing at magnitude –1.5, because its lit hemisphere directly faces us. You'll have no problem finding this ruddy world — it appears as a bright intruder among the background stars of the Gemini twins. The planet easily outshines Gemini's brightest stars, Castor and Pollux, and at opposition shines as brightly as the brightest star in the night sky, Sirius.

After opposition, the Red Planet

MARS IS AT ITS BEST in a telescope during the four-month period between November 1 and March 1, when the planet's apparent diameter is greater than 10".

NEW MARS



John Asztalos

DARK SURFACE MARKINGS on Mars should come into sharp focus this winter, as the planet looms relatively large in your eyepiece and follows a high arc across the sky.

rapidly shrinks in apparent size and fades in brightness. By February 1, Mars appears 13.1" across and shines at magnitude –0.9. And on March 1, the planet is down to 10.2" in apparent diameter and a magnitude of –0.1. However, after opposition, Mars is above the horizon at sunset and so appears prominent during the evening hours.

Although the apparent diameter of Mars at this apparition will not be what it was in either 1988 (23.8") or 1990 (18.1"), telescope users should still see plenty of detail on the planet's disk. Part of the reason is Mars' position high in the northern sky. At opposition Mars lies farther north than at any opposition in the past 15 years.

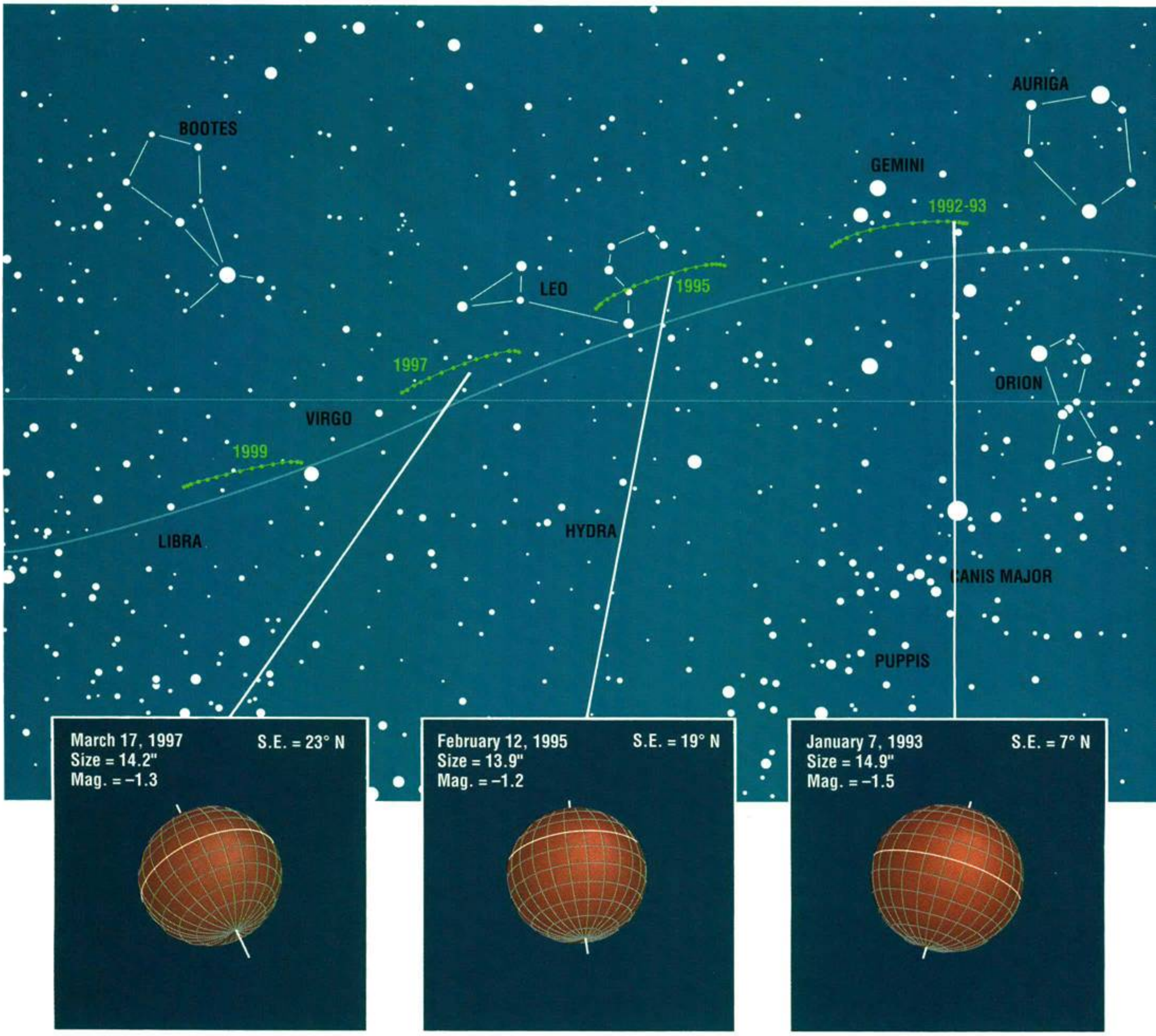
For Northern Hemisphere observers, this means that Mars is higher in the sky when it crosses your local meridian. (Mars crosses the meridian shortly after midnight in December, at midnight around opposition, and in the late evening hours in mid- to late January.) For an observer at 40° north latitude in early January, Mars lies less than 15° from the zenith as it crosses the meridian. At such a high elevation, the shimmering air currents in Earth's atmosphere that cause bad seeing are reduced considerably, and you'll be rewarded with steadier, sharper views of the planet.

Seeing the Details

But even when Mars is high in the sky, it remains a challenging observing target. You'll want to use a high-quality scope at least 3 inches in aperture to spot the white Martian polar caps and some of the mottled features in between. A 6-inch or larger telescope will show you more surface detail when Mars is at its best and extends the period over which you can see some detail.

Good seeing conditions are also a must because atmospheric turbulence will blur or wipe out most of the albedo markings. That's why you'll want to observe when Mars is near the meridian. But it also means you should give your telescope 30 to 60 minutes to cool down to the ambient air temperature before you begin observing.

You'll see the most detail if you use a high-quality eyepiece such as a Plössl or orthoscopic. Also use as high a magnification as the seeing allows. After centering Mars in a



low-power eyepiece, increase the power until you have the highest magnification that still yields a crisp image. You'll then be able to see the most detail your telescope and the night's conditions will allow.

A set of filters (available in most camera stores) will also assist you in viewing the more subtle markings. For surface features, the best filters are red (Wratten 25 or 29), orange (Wratten 21 or 23A), and yellow (Wratten 8, 12, or 15). Red and orange filters heighten the contrast between light and dark features, while yellow filters brighten lowland areas.

For viewing atmospheric phenomena, try green, blue-green, blue, and violet filters. Green filters (Wratten 56, 57, or 58) highlight ground fogs and frost. Blue-green filters (Wratten 64) are more effective for high-altitude phenomena such as ice fogs and haze in the polar regions. Try a blue filter (Wratten 80A, 38, or 38A) to see mid-altitude clouds and limb hazes. And for high-altitude clouds, the polar cap hoods, and limb hazes, violet filters (Wratten 47) work best.

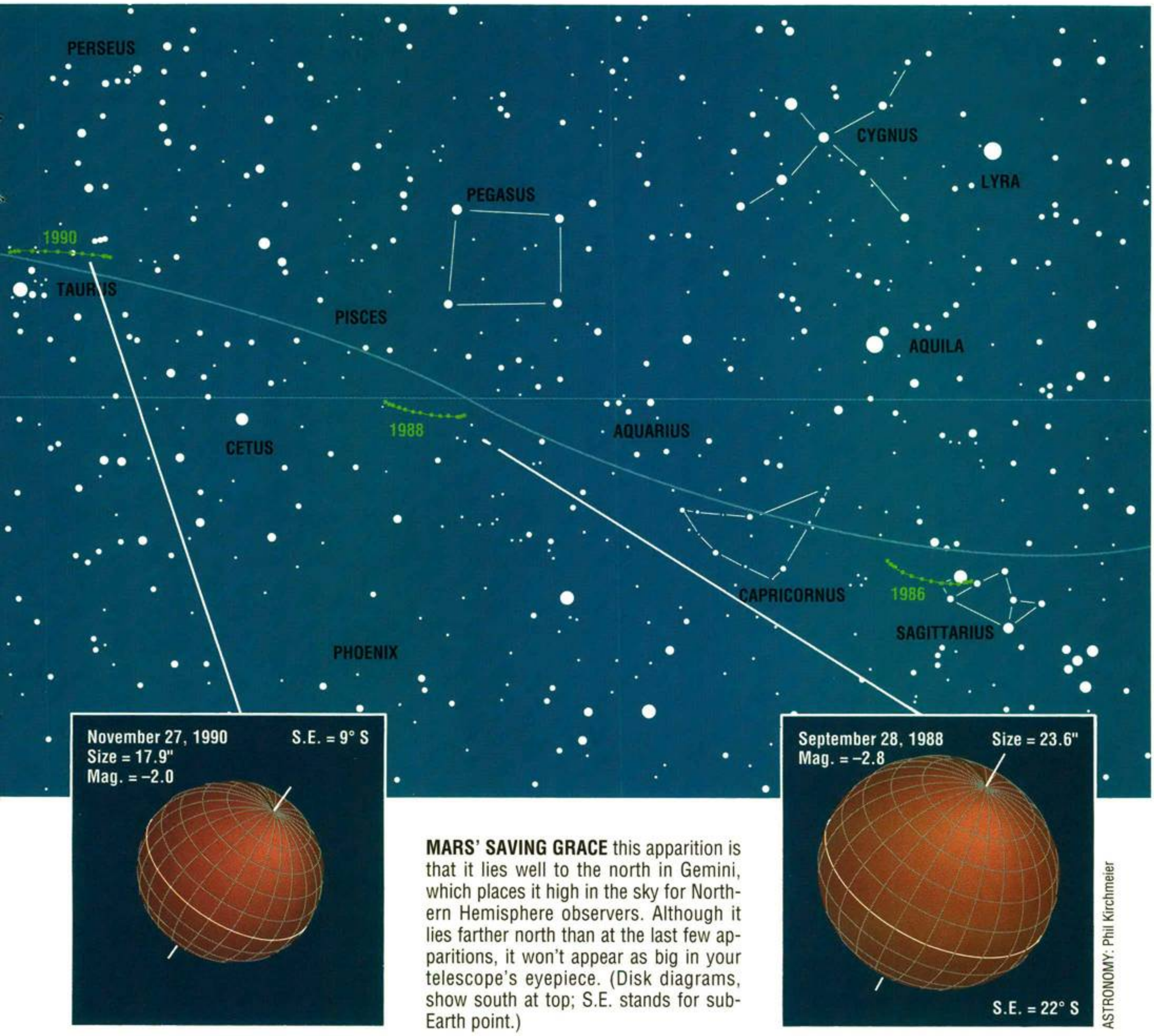
A Blast from the Past

As you look at the Martian surface through your telescope, you'll be following in the footsteps of more than three centuries' worth of astronomers. They, like you, observed Mars during the relatively brief period around opposition when the planet loomed large in their telescopes' eyepieces. Although Galileo and other astronomers observed Mars with the newly invented telescope, the first sketch of the planet didn't emerge until 1636. This first drawing, by an Italian amateur named Francisco Fontana, showed little detail. Christiaan Huygens also did early sketches of Mars. In 1659 he drew for the first time the triangular wedge now called Syrtis Major.

Shortly after the favorable opposition of 1830, several good maps of the planet appeared. They accurately portrayed the distribution of the light and dark markings. In general, the consensus of astronomers was that the darker tracks were oceans and the light areas were continental land masses.

In the 1860s, drawings began to include the famous linear markings, the so-called "canals." The Italian astronomer Angelo Secchi was the first to record these enigmatic lines. He was also the one who introduced the term *canale* for them — an Italian word for channel.

In 1881 Giovanni Schiaparelli made a map that incorporated the



MARS' SAVING GRACE this apparition is that it lies well to the north in Gemini, which places it high in the sky for Northern Hemisphere observers. Although it lies farther north than at the last few apparitions, it won't appear as big in your telescope's eyepiece. (Disk diagrams, show south at top; S.E. stands for sub-Earth point.)

ASTRONOMY: Phil Kirchmeier

linear markings. Altogether, he mapped over 40 of these canals About them, he stated:

"All the vast extent of the continents is furrowed upon every side by a network of numerous lines or fine stripes of a more or less pronounced dark color, whose aspect is very variable. They traverse the planet for long distances in regular lines, that do not resemble the winding courses of our streams."

Unfortunately, *canale* was translated by English-speaking researchers to canal. This error touched off fierce debates, which dragged on for nearly a century, about the possibility of intelligent life on Mars.

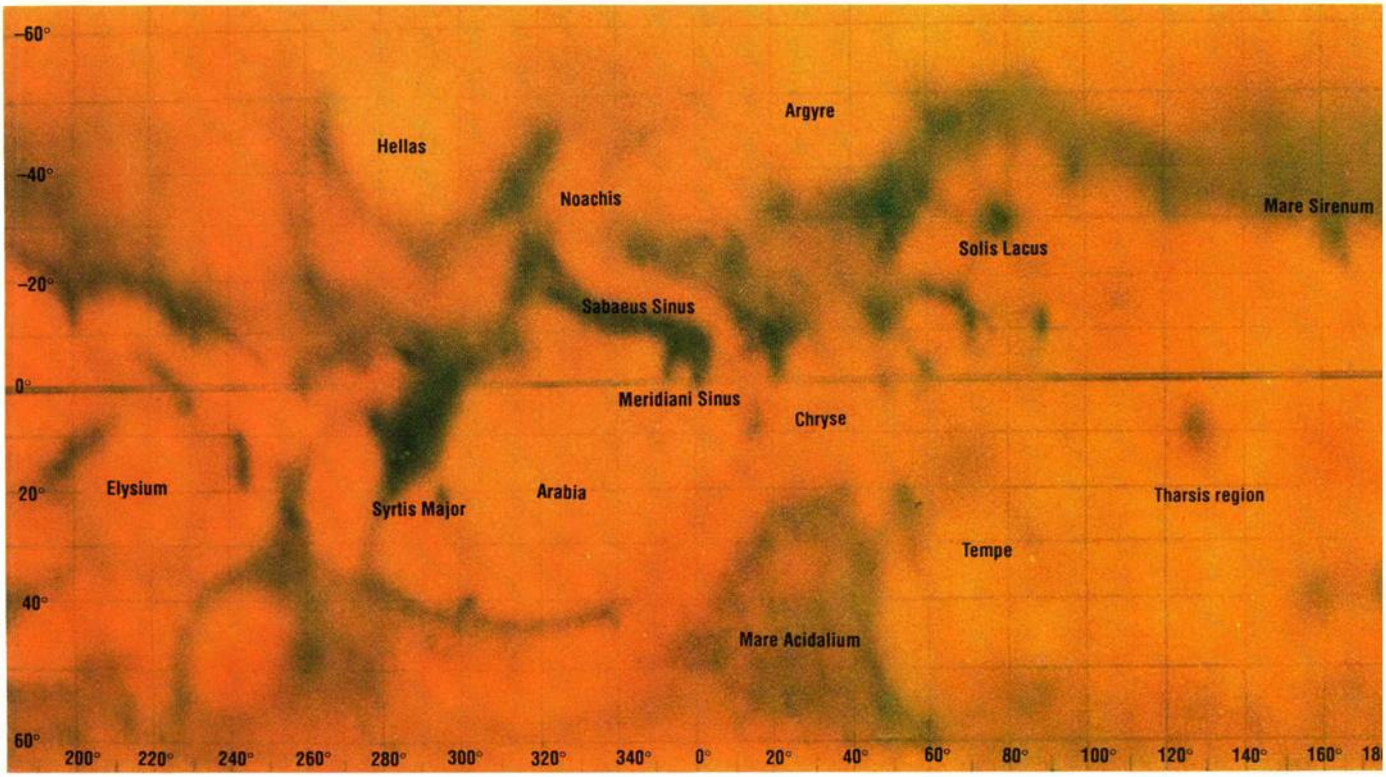
It was an American astronomer, Percival Lowell, who popularized the canal idea through maps and books. An independently wealthy businessman and politician, he constructed, with his own funds, a large observatory at Flagstaff, Arizona. Armed with observations made using his 24-inch refractor, Lowell spoke eloquently of an intelligent, but thirsty, race of beings populating Mars. He and others suggested the canals were artificial waterways that carried sorely needed water from the polar regions to the dry deserts.

Most astronomers of the day rejected Lowell's conclusions, believing that the canals either didn't exist (most observers couldn't see them) or they were purely natural features. Frenchman Eugene Antoniadi explained these odd linear markings as craters or other features that, because of poor resolution, merged to give the appearance of canals. His 1901 map, coauthored with Camille Flammarion, is considered the best ever produced of Mars before the space age.

Today our maps of Mars show considerably more detail than Earth-based observers could ever obtain. Images returned by a series of successful flyby, orbital, and unmanned lander space missions show a world of considerable geological diversity. Towering volcanoes, giant impact basins, dry river channels, and gargantuan canyons litter the Martian landscape.

Comparing Old and New Mars

Spacecraft views of the Red Planet proved that the canals do not exist. But they also showed that many features observed from Earth do coincide with actual geologic structures on the planet. As you prepare to observe Mars this winter, you can expect to see several of these features for yourself. (Use the albedo map and table of central meridian crossings



on this page to determine when the various features are easiest to see.)

As Mars approaches opposition, the planet's south polar cap expands with the onset of autumn while the north polar cap shrinks with the coming of spring. These ice caps are probably the easiest features to see, whether you're a casual or experienced observer. The caps consist of permanent water ice at their centers and variable carbon dioxide ice around their perimeters. Because we are between the seasonal extremes at this opposition, you'll have the opportunity to see the polar areas in a state of transition.

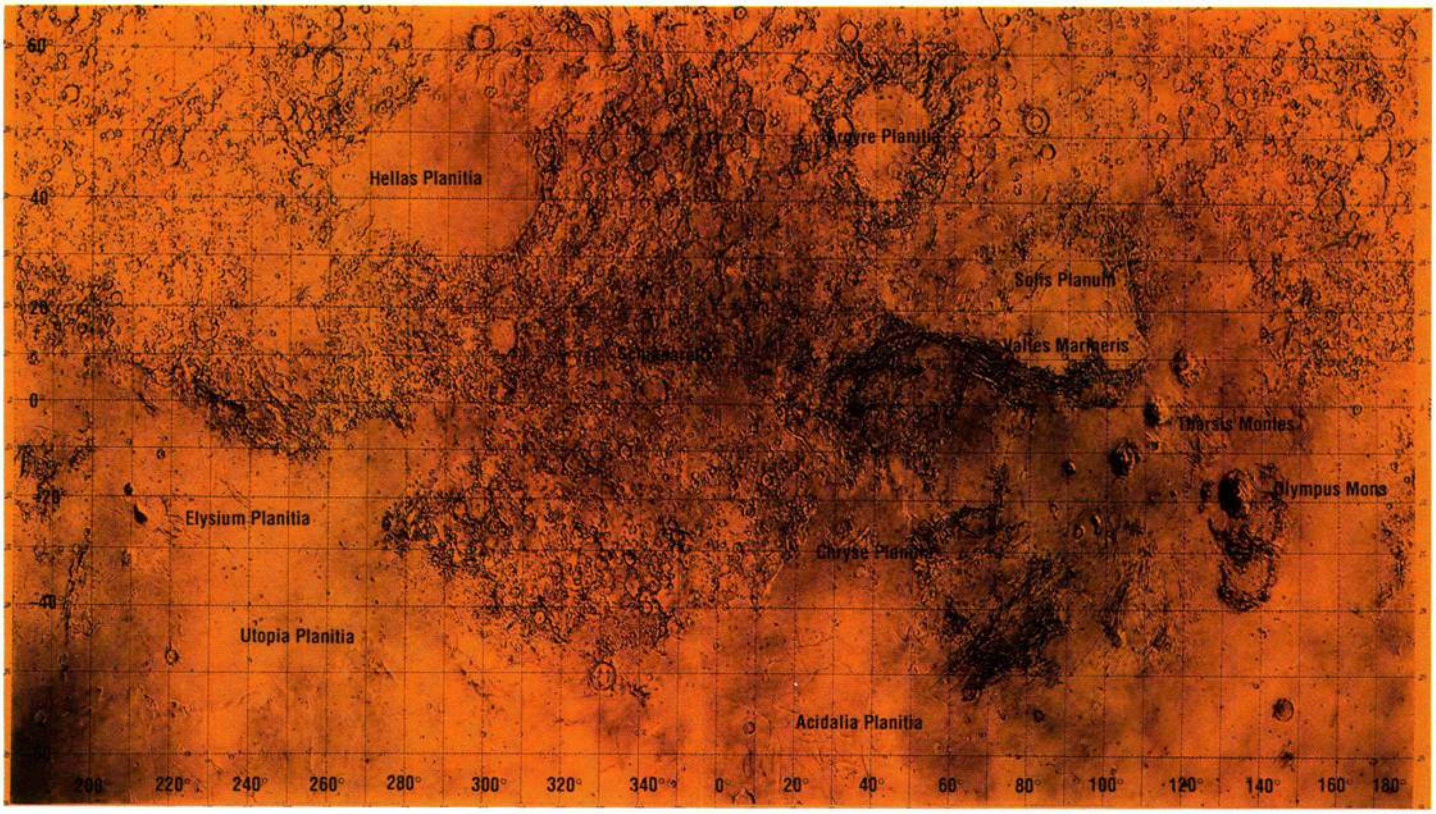
As with our Moon, the surface of Mars is classified into two distinct regions: the lowlands and highlands. When you view Mars through a telescope, these two regions are easy to tell apart. The lowlands are confined primarily to the northern hemisphere, giving that portion of the planet its lighter tone. This half of the planet is a younger landscape composed of volcanic materials.

The southern hemisphere, on the other hand, is considerably darker. The surfaces in this hemisphere are rough because they are covered with impact-generated gravel. On the Flammarion and Antoniadi map of 1901, there is an area called Mare Australe, the southern ocean. Here we are viewing the ancient, heavily cratered uplands. Craters found here probably date back to the period of heavy bombardment that occurred

MARTIAN CENTRAL MERIDIANS

Date	Central Meridian	Date	Central Meridian
October 14	45°	December 31	51°
October 17	17°	January 3	25°
October 20	349°	January 6	359°
October 23	320°	January 9	332°
October 26	292°	January 12	306°
October 29	264°	January 15	280°
November 1	235°	January 18	253°
November 4	207°	January 21	227°
November 7	179°	January 24	200°
November 10	151°	January 27	174°
November 13	123°	January 30	147°
November 16	95°	February 2	120°
November 19	68°	February 5	93°
November 22	40°	February 8	66°
November 25	13°	February 11	39°
November 28	345°	February 14	12°
December 1	318°	February 17	344°
December 4	291°	February 20	317°
December 7	264°	February 23	289°
December 10	237°	February 26	262°
December 13	210°	March 1	234°
December 16	183°	March 4	206°
December 19	157°	March 7	178°
December 22	130°	March 10	150°
December 25	104°	March 13	122°
December 28	77°	March 16	94°

To find surface features on Mars, locate the feature on the albedo map (top) and then determine when it will lie at the center of the Martian disk using this table. It gives the central meridian at 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST) during the period when Mars appears larger than 9" in diameter. To find the central meridian at other dates and times, subtract 9.1° for each day after a tabulated date and add 14.6° for each hour after a tabulated time.



USGS, based on Mariner 9 data

more than 3.5 billion years ago.

Like the largest impact features on the Moon, those on Mars are called basins; Earth-based observers first recorded the three largest unknowingly. The circular features called Hellas, Argyre, and Isidis correspond to major impact basins. Hellas and Argyre show up as huge bright spots within the lowlands (or Mare Australe) while Isidis flanks the eastern edge of the dark Syrtis Major wedge. Hellas is the largest basin, but each of the three impact sites is more than 600 miles (1,000 kilometers) across.

The Great Martian Volcanoes

The lowlands are volcanic plains. This is where you'll find lava flows and enormous volcanoes. Two prominent volcanic regions exist on Mars — Tharsis and Elysium. These areas are the brightest on the planet and quite easy to see from Earth. The Tharsis region apparently contains the youngest terrain on the entire planet. Tharsis is what planetary scientists call a volcano-tectonic rise. Volcanism has been concentrated in this region for so long that a massive bulge of material has clumped up here. The Tharsis region is a wide plateau approximately 6 miles high and 2,400 miles wide. Superimposed on the dome are some of the largest Martian volcanoes. The Elysium region is a smaller and older version of Tharsis, with its own collection of volcanoes.

Through the telescope, backyard astronomers can find at least one volcano, though with some difficulty. Called Nix Olympica on older maps, this is one of the most stunning volcanoes in the solar system — Olympus Mons. Standing three times taller than Earth's highest mountain and about as wide as the state of Arizona, it's no wonder Earth-based observers can see it, albeit only under exceptional observing conditions. (Look for a small circular spot in the Tharsis region.) Historically, Olympus Mons was recorded even when the planet was engulfed in global dust storms. However, early telescope users didn't realize they were seeing a massive mountain protruding through the dusty obscuration.

Besides the volcanoes of Mars (a dozen of which are larger than any found on our planet), one of the most fascinating geologic features is the series of canyons that make up Valles Marineris, or the Mariner Valley (which was named after Mariner 9). On the best Earth-based maps, the area containing Valles Marineris shows up as a dark linear feature just north of Solis Lacus. Lowell mapped it as one of his canals. Extending away from the eastern flank of Tharsis, the canyon is some 2,400 miles long, up to 120 miles wide, and 4 miles deep at its deepest. When you peer at Mars through your telescope, look for this region as an east-west trending feature in the equatorial region, just east of Tharsis.

Finally, we'll complete our tour with a look at the landing sites of Viking. Viking 1 is situated in Chryse Planitia, a bright region just south of Mare Acidalium and east of Tharsis. Viking 2 lies north of Elysium, on the plains of Utopia Planitia. This area also shows up as a bright unit.

Mars is still a mysterious planet. But there's a good chance that shortly after the turn of the century, its dusty plains may sport the footprints of humanity. So these next few oppositions could be our last chance to see Mars as an "unconquered" planet. Although Mars was better placed during the previous two oppositions, this current show shouldn't be missed. For one thing, the next three close approaches are even worse.

In short, take your telescope out this winter and aim it at the fourth world. Ponder its place in the history of planetary astronomy. But most of all, be sure to search for those remarkable markings that have tugged at the curiosity of our species for generations. ☐

THE INTRICATE MARKINGS seen on the surface of the Red Planet from Earth (opposite page) in many cases correspond to actual features recorded by space probes (above).

Edward F. Albin is a planetarium astronomer with the Cherry Planetarium at Fernbank Science Center in Atlanta, Georgia.

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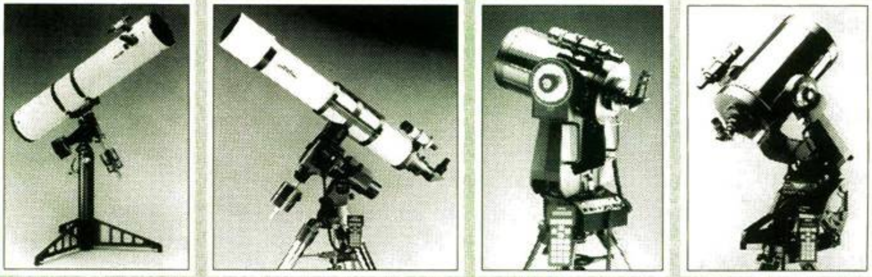

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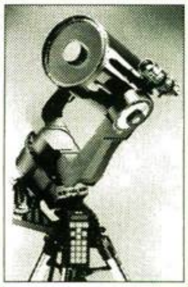

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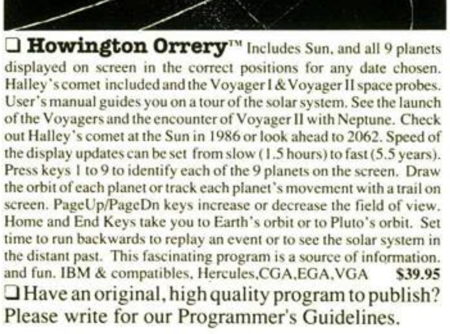

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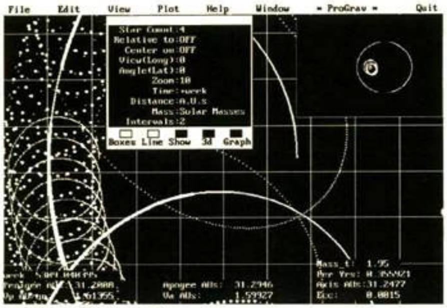

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Mass:Solar Masses
Intervals:2

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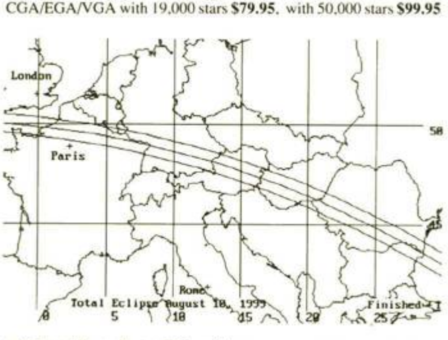

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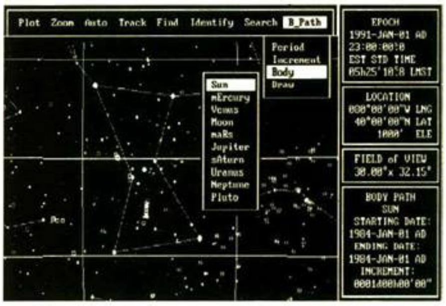

EPOCH
1991-JAN-01 AD
23:00:00:0
EST STD TIME
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LOCATION
080°00'00"W LNG
40°00'00"N LAT
1000' ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
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Partial Solar Eclipse
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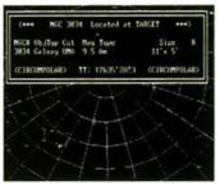
LAST CONTACT



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AUTUMN'S COLORFUL DOUBLE STARS

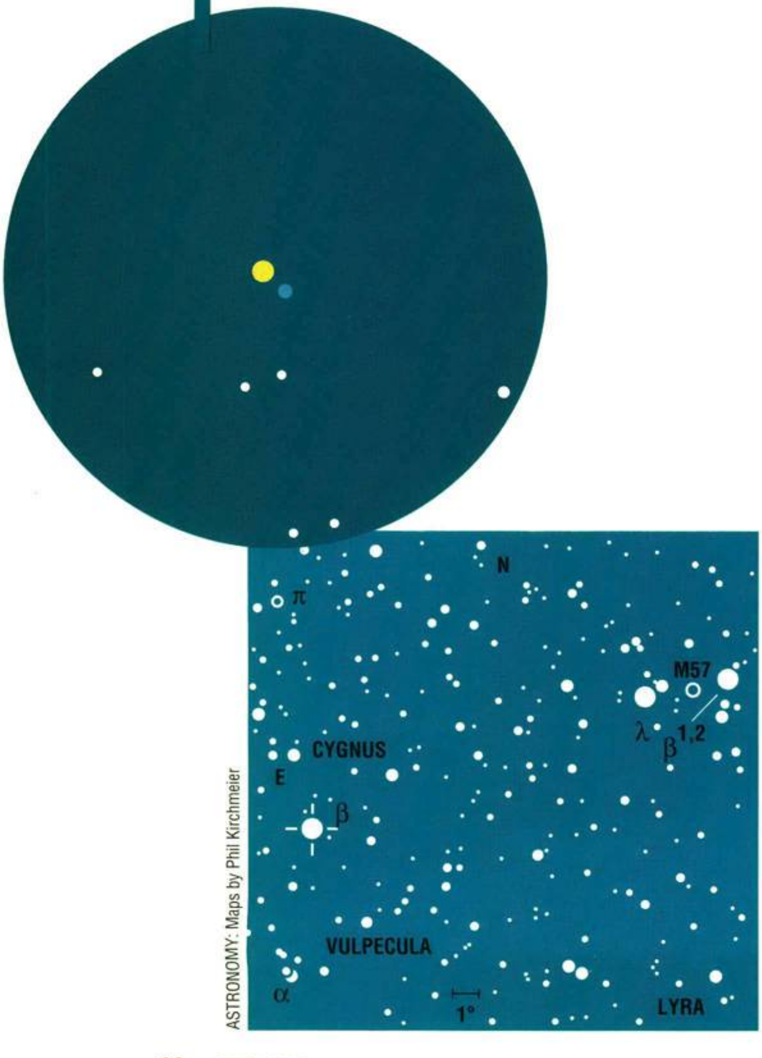
Explore a range of star colors and brightnesses this autumn through the eyepiece of a small telescope.

Text and sketches by Mark T. Stauffer

Albireo

Mags. 3.1 and 5.1

6-inch f/5 reflector at 29x



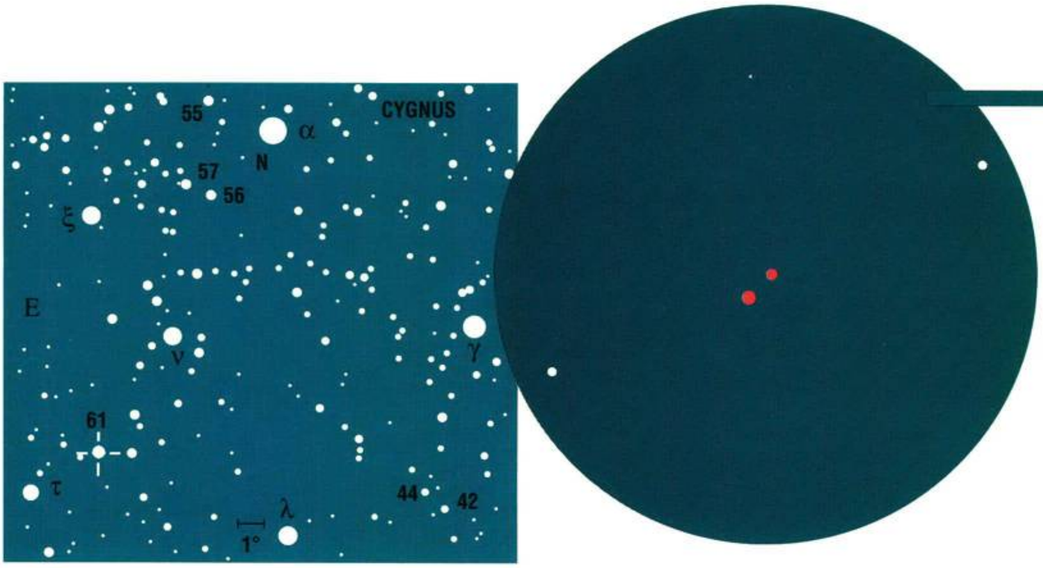
ASTRONOMY: Maps by Phil Kirchmeier

Autumn is a richly colorful time of year, not just within the forests of Earth, but also in the starfields of the night sky. Scattered among single stars in those starfields lie many double stars, systems composed of twin suns orbiting about a common center of mass. Because the component stars are bright and many offer subtly contrasting colors — from blue to yellow to rusty orange — these pairs are beautiful in the eyepiece of a small telescope. The colors are not as brilliant as those in a Disney production, mind you: star colors viewed in the eyepiece are pastel shades that you must look at carefully to perceive. But the colors are there, and after you gain some experience in viewing these doubles, you'll come to appreciate their delicate beauty.

Many such pairs are visible in the autumn evening sky, and an evening's journey into the universe will highlight some of the best. Equipped with a 2-inch to 4-inch telescope and a range of eyepieces, you can find several bright stars easily at low magnification and then switch to high magnification — 100x to 150x — to see if two or more stars are visible. Reserve your double-star viewing for nights of steady seeing, when the atmosphere is stable. That will allow the relatively few photons from the faint secondary stars to reach you unperturbed. Be patient: a few observing sessions may be required before you easily spot the subtle colors.

Our first stop on this exploration is the constellation Lyra, the brightest and most easily recognizable star group in the western evening sky. Besides being home to the famous "double double," Epsilon (ε) Lyrae, Lyra hosts another unusual star, **Zeta (ζ) Lyrae**. When trained on Zeta, the eyepiece of a telescope shows a very different view than the two sets of bright white stars contained in Epsilon Lyrae. Instead, Zeta consists of a wide pair of yellow and blue stars. Low power will split this common-proper-motion pair. I enjoy viewing this lovely duo frequently using a 3-inch f/11 refractor at 35x.

Moving eastward into Cygnus, we come to three wide, beautiful systems, one of which is a triple star. First let's observe **Albireo** (Beta [β] Cygni), located at the nose of the celestial swan or at the foot of the Northern Cross, whichever way you perceive Cygnus. This pair is composed of a deep yellow primary and a



61 Cygni

Mags. 5.2 and 6.0

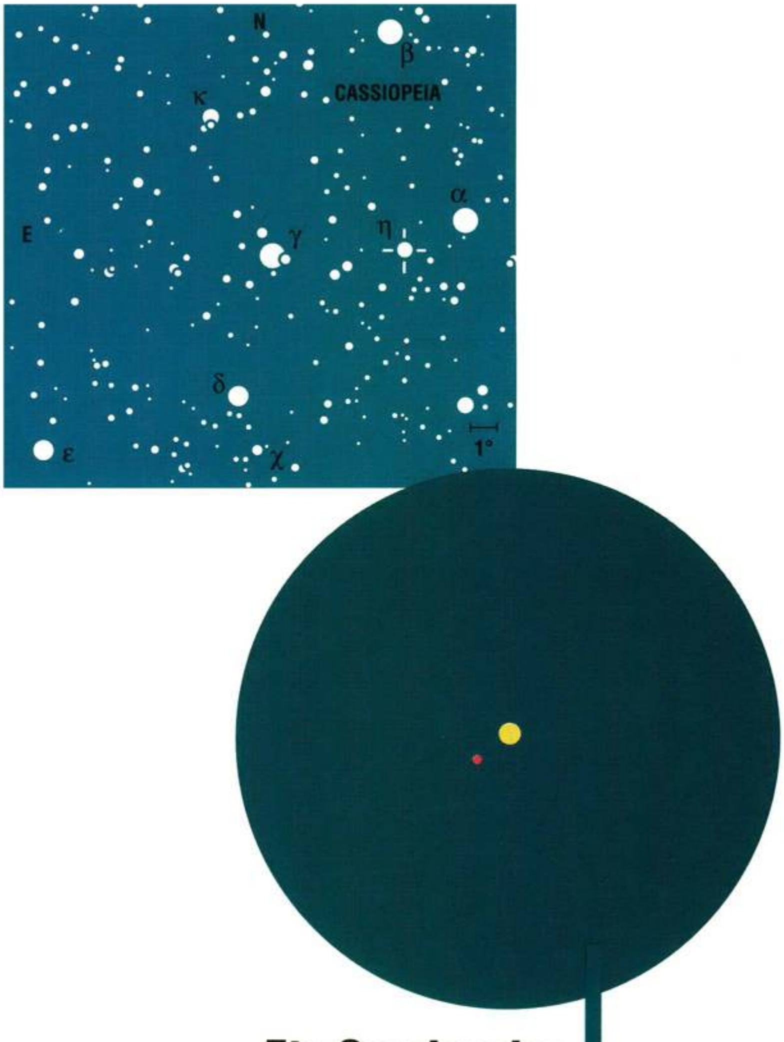
3-inch f/11 refractor at 105x

bluish companion separated by 34" in position angle (p.a.) 54°. The stars are gravitationally linked, traveling together through space. Albireo's stunning colors provide a vivid contrast that has earned this double recognition as the most beautiful in the sky. Albireo is easily split using small telescopes at low magnifications, which show a smattering of background stars in addition to the double. I've used a 6-inch f/5 reflector, 3-inch f/11 and 4-inch f/10 refractors, and a 90mm Maksutov-Cassegrain at powers from 29x to 38x to observe this celestial gem. The best views come from the refractors. How well does your scope show Albireo's remarkable contrast?

Two other noteworthy systems in Cygnus are the wide triple **Omicron (o^1) Cygni** and the binary **61 Cygni**. Omicron^1 Cygni, also known as 31 Cygni, lies about 7° southwest of Deneb. It is composed of a 4th-magnitude yellow-orange primary, a 5th-magnitude bluish white companion (30 Cygni) at a distance of 360" and p.a. of 338°, and a 7th-magnitude blue star 107" from the primary. Though the triple is optical — that is, the stars aren't physically related — the three stars form a wonderful group for small telescopes at low magnification. When you observe Omicron^1 Cygni, do you see one of the companions as more bluish than the other?

The binary star 61 Cygni, situated 5° northeast of Lambda (λ) Cygni, contains orange-colored stars with an orbital period of 653 years. The current angular separation of 61 Cygni's 5th- and 6th-magnitude components is 29" in p.a. 146°. It's an easy pair to split for small telescopes using low powers — I've used my 3-inch f/11 refractor at 35x. This system is historically significant: in 1838 the German astronomer Friedrich W. Bessel measured its distance from the Sun by means of parallax, the first such determination. This twin system comprises the fourth nearest star, lying a mere 11 light-years away.

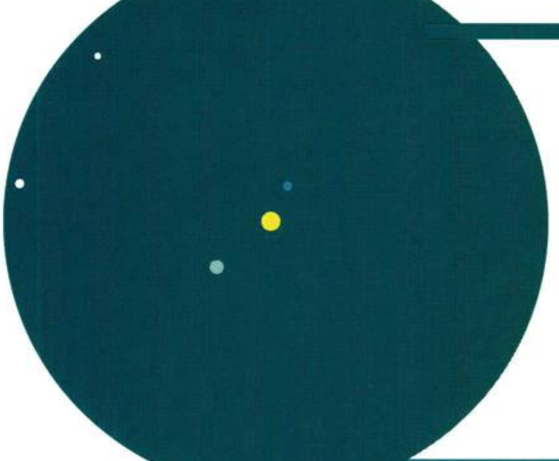
Let's now proceed southeast of highly populated Cygnus into sparsely populated Equuleus, the Little Horse. **Epsilon Equulei** has a white, magnitude 6.0 primary star. The color contrast comes from a 7th-magnitude blue companion lying 10.7" from the primary at p.a. 70°. I used a 3-inch f/11 refractor at 35x and 61x to view this pretty double. Epsilon Equulei is easy enough at low magnifications, but moderate powers may yield a slightly better view, as I found when I used the



Eta Cassiopeiae

Mags. 3.4 and 7.5

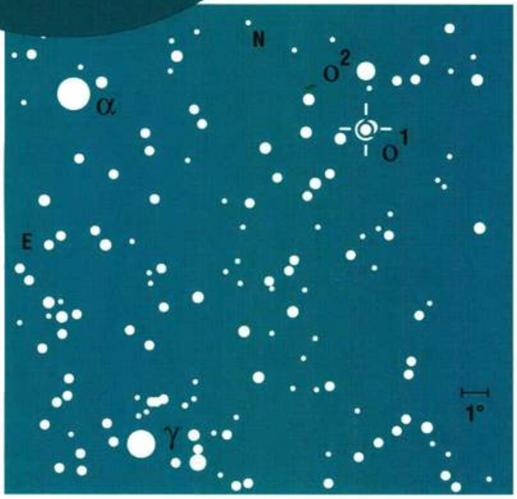
3-inch f/11 refractor at 105x



Omicron^1 Cygni

Mags. 3.8 and 4.9

3-inch f/11 refractor at 35x



3-inch refractor at 61x. Try this with your own scope and judge for yourself.

Venturing farther south into the realm of the celestial Sea-Goat, Capricornus, we find yet another colorful autumn pair, **Beta Capricorni**. This pair is very wide, with the 3rd-magnitude pale orange primary and 6th-magnitude blue-white secondary separated by 205" in p.a. 267°. Beta's stars provide a marvelous contrast that stands out beautifully in small telescopes. I've found the best view comes with the 3-inch refractor at 35x.

Let's now leave Capricornus and head northward toward the finest double star in this region of the autumn evening sky, **Almach** (Gamma [γ] Andromedae). If you thought Albireo had no rival, aim your scope at this star. Almach's orange 2nd-magnitude primary star and its blue 5th-magnitude companion produce a breathtaking contrast that many observers claim equals or even surpasses the striking contrast displayed by the components of Albireo. Though Almach's primary and companion are separated by nearly 10", medium-to-high magnifications are usually better for viewing the component stars. I found this to be true when I observed Gamma Andromedae though my 3-inch f/11 and 4-inch f/10 refractors at 61x to 100x. The companion was visible more distinctly, and the remarkable color contrast of Almach still evident. See for yourself if higher powers give a better view of Almach's bluish companion.

No survey of colorful autumn double stars would be complete without taking in the Queen constellation, Cassiopeia. Superb doubles in this bright constellation include **Schedar** (Alpha [α] Cassiopeiae) and **Eta (η) Cassiopeiae**. Schedar is a quadruple whose deep yellow 2nd-magnitude primary and 9th-magnitude blue secondary are separated by 64". I've typically viewed Schedar with a 3-inch refractor at 35x. Eta Cassiopeiae is a binary whose 3rd- and 7th-magnitude component stars orbit each other every 480 years. The companion has been described as red, tawny yellow, orange — even purple! Through my 3-inch and 4-inch refractors at 61x and 67x, I've seen a yellow primary and orange companion. What colors do you see in Eta Cassiopeiae?

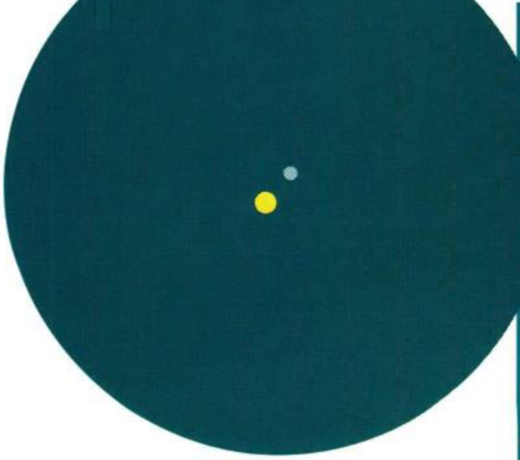
Two final pairs in Cassiopeia offer a challenge for small scopes. **Struve 163** (Σ163), situated approximately 1° north-northwest of Epsilon Cassiopeiae, is a wide duo with lovely orange and blue component stars of magnitudes 7 and 9 separated by 35". The contrast is superb. I've observed Σ163's eyecatching contrast using my 90mm catadioptric scope and 4-inch refractor, both at 38x.

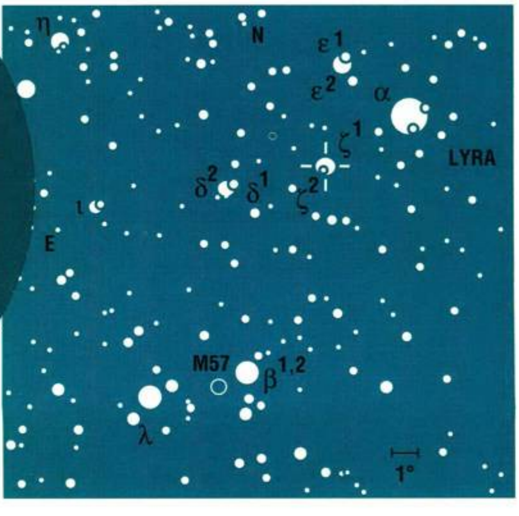
Iota (ι) Cassiopeiae is a fine, nicely contrasted triple system, with a yellowish 5th-magnitude primary accompanied by close, blue-white 7th-magnitude and blue

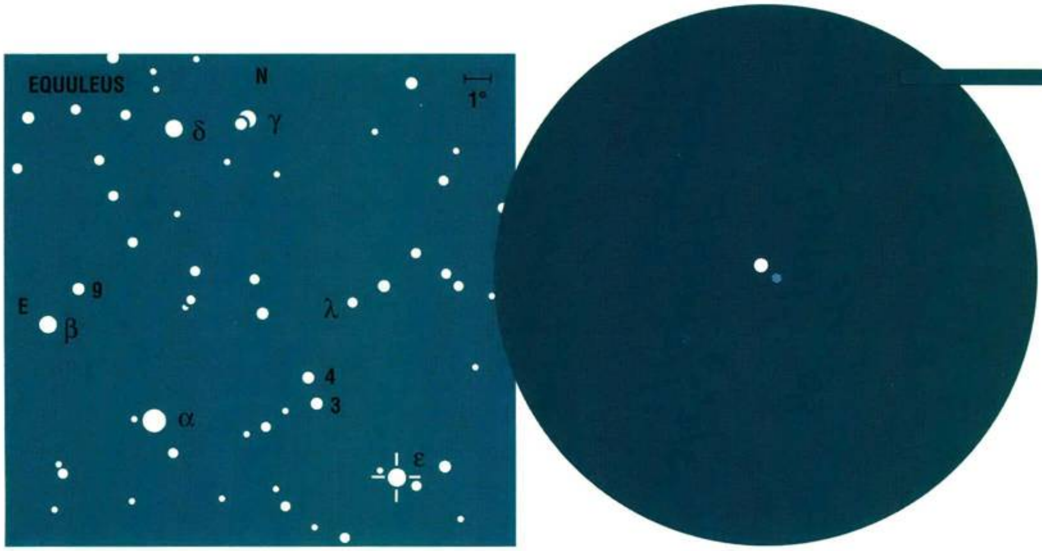
Zeta Lyrae

Mags. 4.4 and 5.7

3-inch f/11 refractor at 105x





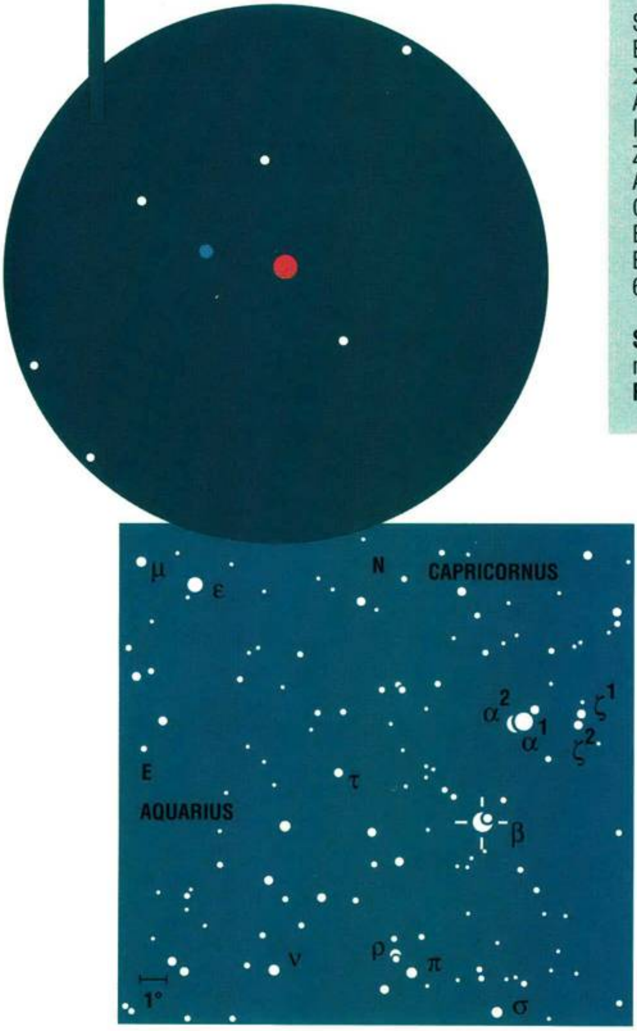


Epsilon Equulei

Mags. 6.0 and 7.1
3-inch f/11 refractor at 61x

Beta Capricorni

Mags. 3.4 and 6.2
6-inch f/5 reflector at 29x



AUTUMN DOUBLES FOR SMALL TELESCOPES

Star	R.A. (2000.0)	Dec.	Mags.	Sep.	P.A.
Schedar	0h40.5m	+56°32'	2.2, 8.9	64"	280° (1913)
Eta Cassiopeiae	0h49.1m	+57°49'	3.4, 7.5	14"	— —
Σ163	1h51.3m	+64°51'	6.8, 8.8	34.8"	35° (1936)
Almach	2h03.9m	+42°20'	2.3, 5.3	9.8"	63° (1967)
Iota Cassiopeiae	2h29.1m	+67°24'	4.6, 6.9, 8.4	2", 7.2"	234°, 114° (1968)
Zeta Lyrae	18h44.8m	+37°36'	4.4, 5.7	60"	—
Albireo	19h30.7m	+27°58'	3.1, 5.1	34.4"	54° (1967)
Omicron^1 Cygni	20h13.6m	+46°44'	3.8, 4.9	360"	—
Beta Capricorni	20h21.0m	−14°47'	3.4, 6.2	205.3"	267° (1922)
Epsilon Equulei	20h59.1m	+4°18'	6.0, 7.1	10.7"	70° (1967)
61 Cygni	21h06.9m	+38°45'	5.2, 6.0	29"	—

Star: star name; **R.A. and Dec.:** coordinates of star for equinox 2000.0; **Mags.:** V magnitudes of component stars; **Sep.:** separation between stars in arcseconds; **P.A.:** position angle of separation with last year of measurement.

8th-magnitude companions. Iota Cas AB is a binary system with an 840-year orbital period that is currently separated by 2" in p.a. 234°. The third star, separated from the primary by 7.2" in p.a. 114°, is a physical member of the system. My best views of this triple came from my 4-inch refractor at 100x and 200x. High magnifications nicely resolve Iota's component stars, particularly the closest companion. Don't pass up Iota Cas while exploring the rich Cassiopeia starfields this autumn. These doubles will provide you with endless observing enjoyment. And unlike faint, challenging nebulae, they will delight you on less-than-perfect nights or from moderately light-polluted sites. Armed with a small telescope, you can discover the beauty of autumn's double stars. ☐

Mark T. Stauffer is an observer living in Pittsburgh. He is a former president of the Baton Rouge Astronomical Society in Louisiana.

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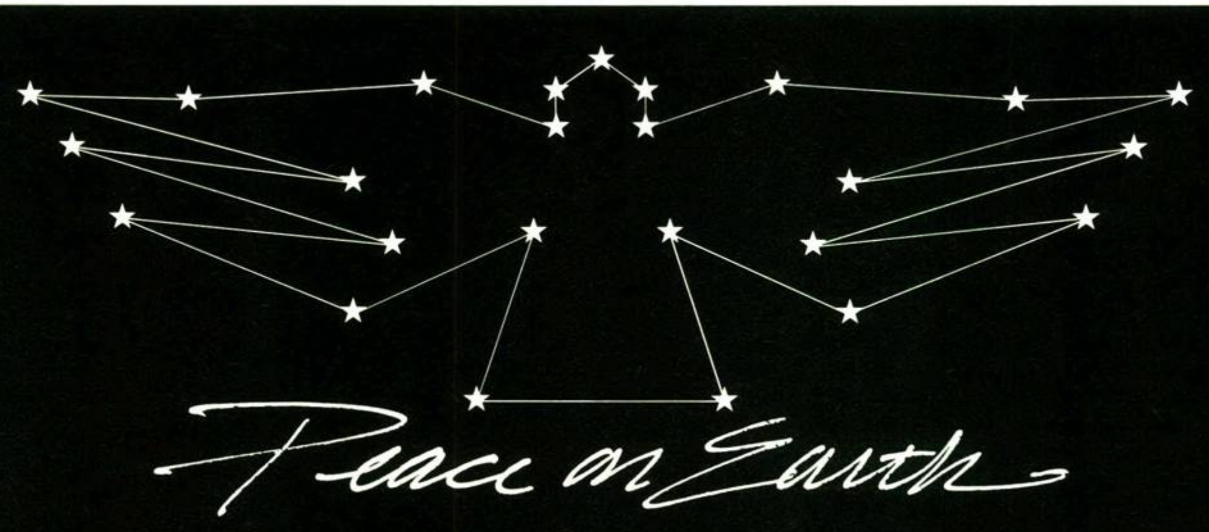

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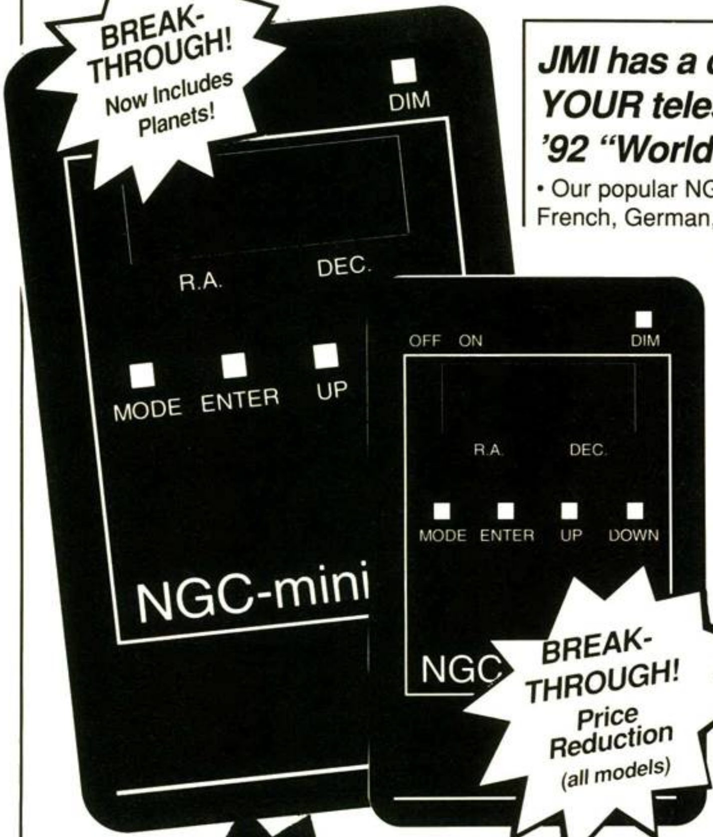

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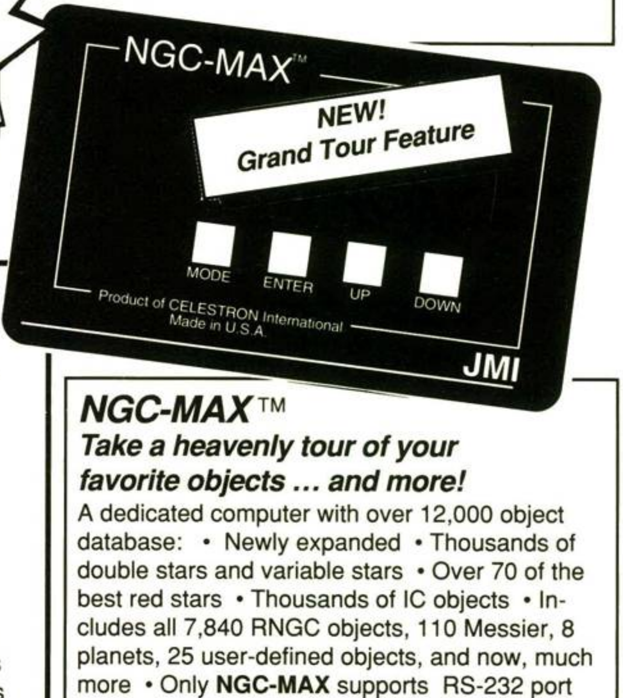

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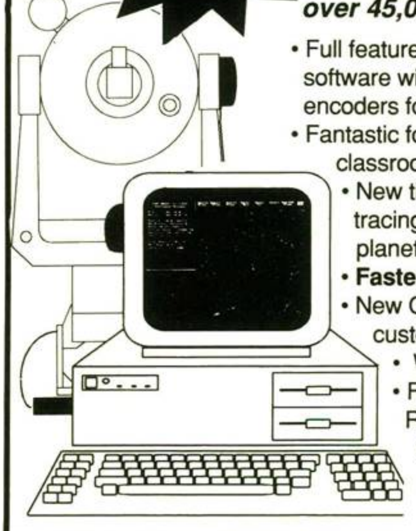

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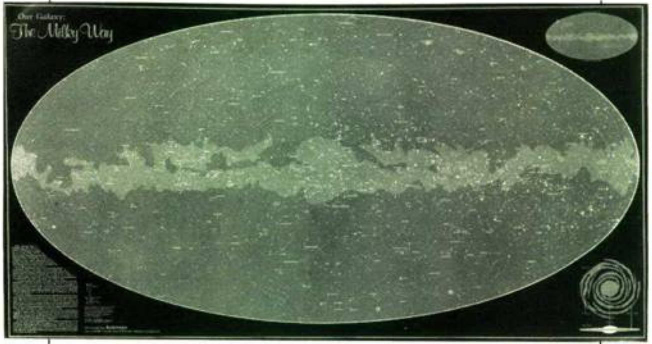

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SUMMER CLUB OBSERVING

Summer nights mean warm temperatures and the beautiful arch of the Milky Way gracefully shimmering overhead. The summer of 1992 was no exception, and astronomy clubs around the country lost little time in organizing stargazes for their members and interested newcomers.

The Escambia Amateur Astronomer's Association (EAAA), for example, held several stargazes in Florida around the Pensacola area. "On June 5 we held a public gaze at Fort Pickens," says Wayne Wooten, editor of the EAAA's newsletter, *The Meteor*. "About 30 people showed up, including cub scouts from Pack 499, Tiger Den 3. The skies were partly cloudy, yet we were able to show budding observers a transit of Jupiter by Io."

The weather cooperated more fully during the EAAA-sponsored observing session of the lunar eclipse on June 14-15. Says Wooten: "A number of club members — Margaret Hildreth, Jim Lardusky, Jerry Kobi, Warren Jarvis, and Dave Halupowski — hosted some 40 people who watched Earth's shadow paint across the Moon." Wooten and the EAAA members remarked that the eclipse seemed to begin rapidly, but because the Moon's path was below the center of Earth's shadow, the naked eye appearance of the Moon changed little during the middle phases of the event. "We did a few crater timings, looked at some interesting features near Tycho, and were impressed by the darkness of the eclipse," remarks Wooten. "Had the eclipse been total, the Moon might have completely disappeared!"

Jose Olivarez, Jupiter Recorder for the Association of Lunar and Planetary Observers (ALPO), spent a part of spring and summer 1992 keeping a close watch on the cloud features of the largest planet. During the first seven months of the year, Olivarez reports, Jupiter "looked dull and quiescent to most casual observers because of the overall lack of sharp contrast between the belts and zones." However, this appearance was misleading. "Perceptive observers using high-resolution telescopes noticed rapidly moving spots, an intensifying Great Red Spot, orange, blue, white, and brown color in the planet's Equatorial Zone, and an unusually bright North Temperate Zone.

"The most notable Jupiter event of the year," says Olivarez, "was the return to visibility of rapidly moving dark spots along the southern edge of the North Temperate Belt." These objects were easily observable at high power and resembled spots in this area recorded by observers in 1964 and 1965. The present group of dark spots was discovered on November 18, 1991, by the Japanese observer Isao Miyazaki. He and other ALPO observers followed it through March 31, 1992. "The spots moved at the astonishing rate of 2° of Jovian longitude per day," remarks Olivarez. "The rotation velocity of these dark spots corresponds to 9 hours and 49 minutes — the shortest known on Jupiter." □

ASTRONOMY wants to hear about your observations of the sky. Please send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.

JUPITER WAS A FAVORITE object for telescopic observers last spring (above). Photo by Donald C. Parker. The Milky Way sweeps overhead during a warm summer night on Palomar Mountain, California (below). Photo by Chris Cook.

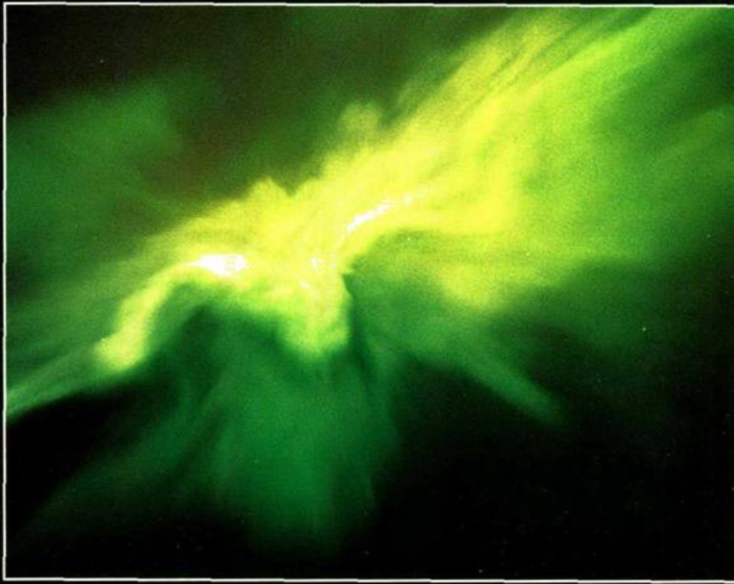
HERE COMES THE SUN

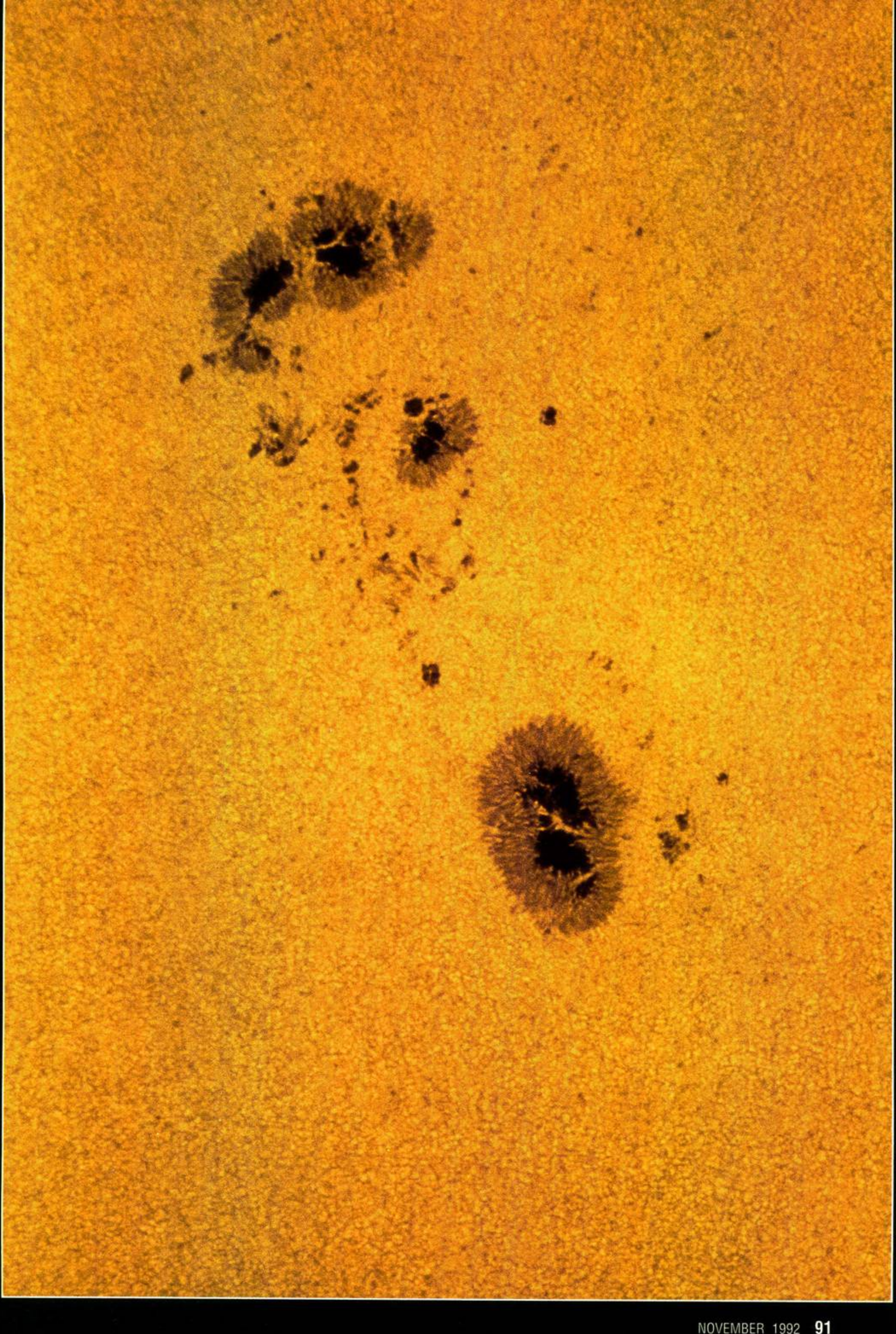
Eckhard Slawik's high-resolution photo of sunspots on July 3, 1992 (opposite page), wins this month's $100 "Best Astrophoto" award. Slawik, of Eggstatt, Germany, captured magnificent detail in the spots and the granulation by using a 6-inch f/9 apochromatic refractor, Agfaortho 25 film, and a 1/250-second exposure.

Readers continue to send ASTRONOMY numerous impressive aurora photos — we wish we could publish them all! A particularly striking array of coronal streamers shows in R. L. Wagner's image of the November 8, 1991 aurora (below). Wagner photographed the display from near Ottawa, Ontario.

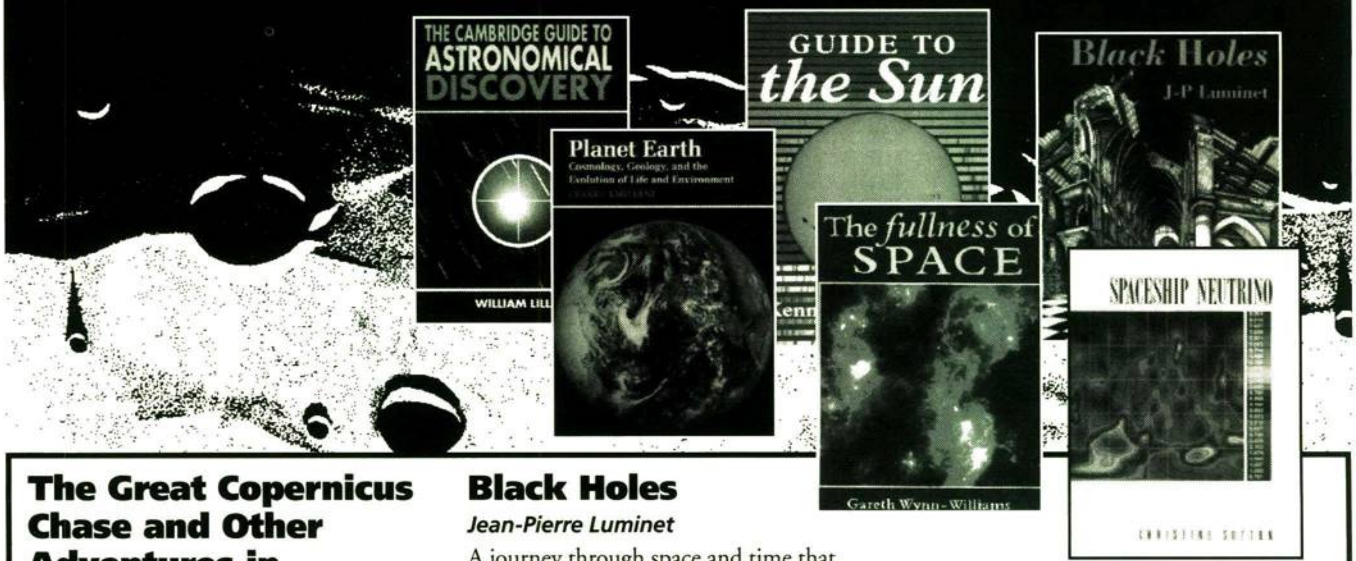
Last summer Chris Cook of Long Beach, California, created a superb portrait of the 5-meter Hale telescope dome on Palomar Mountain, California (below, left).

Challenging deep-sky objects captured the attention of summer astrophotographers, as evidenced by Martin C. Germano's image of the elusive ring-shaped planetary nebula Abell 39 in Hercules (left) and James R. Foster's image of the distorted galaxy NGC 4449 in Canes Venatici (bottom), which shows clumpy star-forming regions.





Cambridge Explores the Skies with New Astronomy Books



The Great Copernicus Chase and Other Adventures in Astronomical History

Owen Gingerich

"...a well-written and compelling set of essays that will make for easy and enjoyable reading. These essays are presented as good-natured meanderings by someone intimately familiar with the subject matter— and deeply in love with it to boot."— David H. DeVorkin, *Sky and Telescope*

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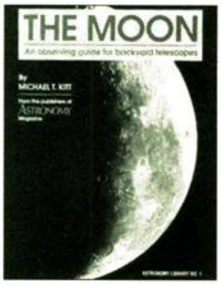

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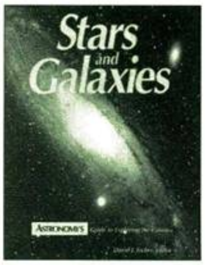

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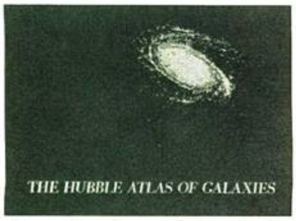

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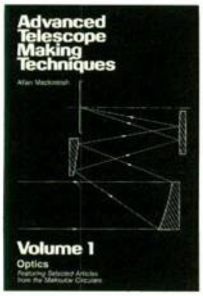

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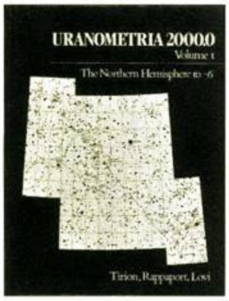

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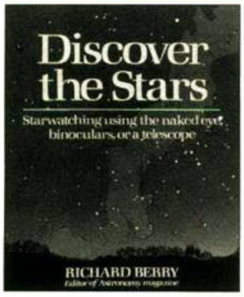
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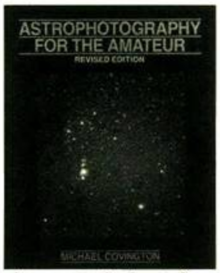

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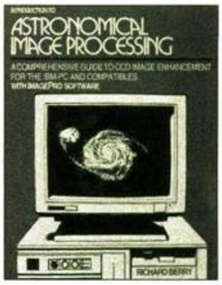
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Swarovski Optik North America, 1 Wholesale Way, Cranston, RI 02920, (800) 426-3089. SLC-7x42 B: $925; SLC-10x42 WB: $995.

2 New Nikon 10x70 Astroluxe

Created for astronomy enthusiasts and wildlife observers, the 10x70 IF SP Astroluxe binocular replaces the previous 10x70 IF HP model. The new model employs the same low-dispersion optical glass found in the Nikon 7x50 IF SP Prostar. The 88-ounce Astroluxe features multicoated optics that are stated to be free from coma and corrected for virtually all chromatic and spherical aberrations. It has independently sealed, nitrogen-filled ocular tubes and individual eyepiece focus for waterproof integrity.

Nikon Sports and Recreational Optics, 1300 Walt Whitman Road, Melville, NY 11747, (800) NIKON US. $1,700.

3 New Binoculars from Steiner

The Admiral Gold 7x50 binoculars from Steiner (top) feature an exclusive CAT™ (color adjusted transmission) lens coating that reduces ultraviolet and infrared light. The CAT coating is applied up to nine times on all air-to-glass surfaces. The Admiral Gold is housed in a blue, rubber-armored body and features large eye-lens oculars with fold-down eye cups. For marine use, an Admiral model is also available with a fluid-damped compass.

The Big Horn (bottom) is a new 9x40 armored binocular that features a slim profile and 26-ounce weight. The field of view is 5.7°, the porro prisms are BaK4 glass, and the eye relief is 20 mm. Soft, rubber fold-down eye cups are standard.

Steiner Binoculars, c/o Pioneer Marketing and Research, 216 Haddon Avenue, Suite 522, Westmont, NJ 08108, (609) 854-2424. 7x50 Admiral Gold: $1,099; Admiral/Compass: $1,599; 9x40 Big Horn: $679.

4 Celestron ED models

This premium series of binoculars features ED (extra-low dispersion) glass in the objectives to virtually eliminate chromatic aberration while enhancing image brightness and contrast. Due to the slightly lower magnification, the 6.5x44 model is 16 percent brighter than equivalent 7x units, and the 9.5x44 model is 11 percent brighter than equivalent 10x units. The prisms are BaK4 glass and all optical surfaces are multicoated. Field of view and eye relief for the 6.5x model is 7.5° and 20 mm respectively, and for the 9.5x model, 6° and 16 mm. Each weighs 26 ounces.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (310) 328-9560, FAX: (310) 212-5835. 6.5x44: $790; 9.5x44: $780.

5 The Latest from Unitron

Unitron's new line of giant astronomical binoculars (right) includes 10x70, 11x80, and 20x80 models with fields of view of 5°, 4.5°, and 3.5° respectively. Each features fully coated optics and BaK4 prisms.

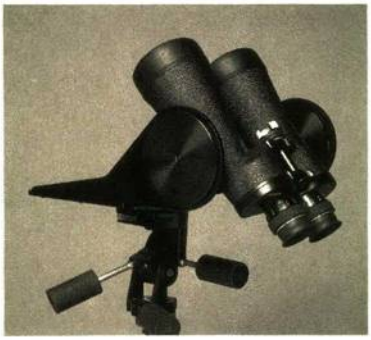
Unitron has also introduced a series of economical binoculars (left) with the Unifocus fast-focus mechanism. Available in 7x35, 8x40, and 7x50 sizes, the binoculars feature coated optics, rubberized objective rims, fold-down rubber eyecups, and carrying case. The 8x40 is a wide-angle model with a 9° field of view.

Unitron Inc., 170 Wilbur Place, P.O. Box 469, Bohemia, NY 11716, (516) 589-6666, FAX: (516) 589-6975. 7x35: $105; 8x40: $105; 7x50: $105; 11x80: $550; 20x80: $605; 10x70: $1,040.

6 Steadi/Scan Binocular Mount

Safari Telescopes' binocular platform can accommodate binoculars up to 25x125. It is made of 1/4" black anodized machined aluminum and attaches to any sturdy tripod. The platform uses Dobsonian-style bearings to provide smooth altitude and azimuth motions without the need for locks or counterweights while allowing the binoculars to maintain their position when released.

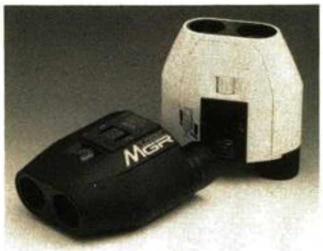
Safari Telescopes, 110 Pascack Road, Pearl River, NY 10965, (914) 735-4163. $149.50 plus $4.50 for UPS shipping.



7 Power Zoom Binoculars

The "LOOK" binoculars made by Copitar feature electrically driven zoom lenses powered by two AAA batteries. Black-finish and white-finish models are available. Both are 7 to 15 power and have 25mm-aperture lenses, making them best suited for daytime viewing. Both feature multicoated lenses, BaK4 prisms, retractable rubber eyecups, soft case, and neck strap.

Distributed by Cameron International, 17 Renwick Avenue, Huntington, NY 11743, (516) 271-4980, FAX: (516) 271-9747. Both models: $229. Call or write for a catalog and for names of dealers in your area.



This department presents new product announcemnts issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

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Retail value: $4300.

One Grand Prize will be awarded in February 1993 from all entries.

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★ To enter, complete the Official Entry Form bound into this issue.

★ You may use the Official Entry Form (no reproductions, please) to subscribe to ASTRONOMY, but you do not have to subscribe to enter. If you're already a subscriber, this is the perfect opportunity to renew your subscription.

★ The Grand Prize will be awarded once from all entries.

★ First, Second and Third prizes will be awarded three times: once from the November 1992 entries, once from the December 1992 entries and once from the January 1993 entries.

★ Send in the Official Entry Form from the November 1992, December 1992 and January 1993 issues of ASTRONOMY and triple your chances of winning!

★ If the Official Entry Form is missing from this magazine, send a postcard with your name, address, home phone number and this magazine's issue date to: ASTRONOMY Sweepstakes, P.O. Box 1612, Waukesha, WI 53187-1612. Cards must be postmarked by the last day of the month of the cover date of this issue. Entries are limited to one per person per month.

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Three Second Prizes will be awarded from each month's entries (November, December and January)–nine total.

3rd Prize

3–year Subscriptions

Last, but certainly not least, each month eight winners will be awarded a three-year subscription to ASTRONOMY magazine. If you are a current subscriber, the prize will begin after your subscription expires.

Eight Third Prizes will be awarded from each month's entries (November, December and January)–24 total.

No purchase necessary. All prizes will be awarded.

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2. Entries are limited to one per person per month. To be eligible for monthly prize awards, entries from the November issue must be postmarked by November 30,1992, entries from the December issue must be postmarked by December 31,1992 and entries from the January issue must be postmarked by January 31,1993. Monthly prizes will be selected in December 1992, January 1993 and February 1993. All entries must be postmarked by January 31, 1993 to be eligible for the Grand Prize, to be awarded in February 1993. Monthly prize winners will become ineligible for future monthly awards, but will be eligible to win the Grand Prize. All entries qualified under these rules will be eligible for the Grand Prize.

3. Winners will be selected in random drawings and decisions are final. Winners will be notified by mail and/or telephone. Any prizes returned as undeliverable will be awarded to alternate winners. Chances of winning are determined by the total number of entries received.

4. Taxes on prizes are the sole responsibility of the winners. No substitutions will be made for any prize offered. All prizes will be awarded.

5. Sweepstakes is open to residents of the U.S. and Canada. Employees and stockholders of Kalmbach Publishing Co., and their families are ineligible. Sweepstakes is subject to all federal, state and local laws and regulations and is void wherever prohibited by law.

6. For a complete list of winners, send a self-addressed stamped envelope to:

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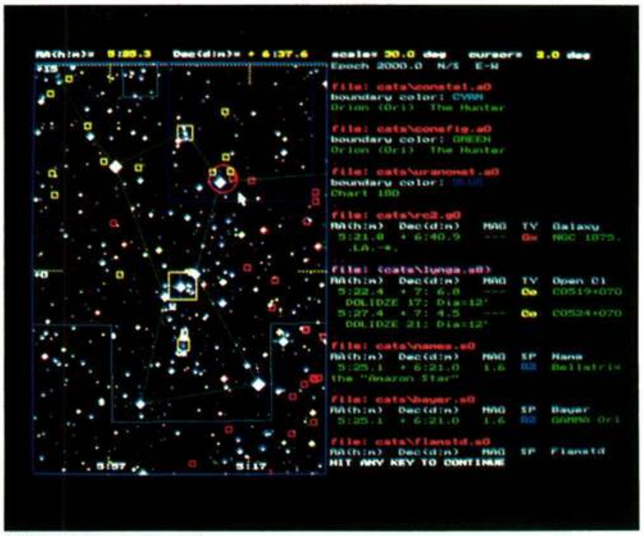
***HyperSKY II** (version 920212), Willmann-Bell, Inc., P.O. Box 35025, Richmond, VA 23235. Phone (804) 320-7016. $49.95. Minimum requirements: IBM PC-compatible computer, mouse, 350 KB of free RAM memory, and CGA display. Math coprocessor, mouse, and VGA display are recommended. Basic program requires 500 KB of hard disk space, but full installation of included catalogs requires up to 2.3 MB of disk space. Optional catalogs require additional hard disk space.*



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ASTRONOMY: Darla Gawelski

Observers of galaxies and star clusters take note: HyperSKY II produces sky charts and observing lists that make those late-night sessions looking for faint fuzzies easier — no need to plot the coordinates of an object by hand on a field atlas, puzzle out the orientation of an inverted telescopic view versus the one in the atlas, or wonder how you're going to get the coordinates of an object from a catalog you can't afford.

HyperSKY prints maps (Epson printers or compatibles only) in a variety of ways. Landscape (sideways) or portrait (normal) modes are available, as are controls to invert the map east/west or north/south. The dot-matrix maps are satisfactory, but a laser printer driver would be a nice add-on.

Screen displays of sky maps show each type of object in a different color for easy identification. You can choose between a half-screen and a full-screen display. HyperSKY also lets you set the angular size of the sky map with full zoom-in and zoom-out capability. And you can control the limiting magnitude (both bright and faint limits) for each type of object to really customize your sky maps and observing lists.

The basic data files included with HyperSKY include over 46,000 SAO stars down to 8th magnitude, 4,362 objects from the *Second Reference Catalogue of Bright Galaxies* (RC2), 129 globular clusters from Kukarkin's catalog, and 1,180 galactic clusters from Lynga's *Catalogue of Open Cluster Data.* Identifications for stars include common names and Bayer and Flamsteed designations as well as constellation names. The constellation figures and IAU boundaries appear on the maps as do the outlines for charts from several popular atlases, including *Uranometria* and the *AAVSO Variable Star Atlas.*

If these catalogs aren't enough for your observing needs, optional catalogs are available at a nominal cost. For example, the *Uppsala General Catalog of Galaxies* (UGC; 12,890 objects) is only $19.95 and the *Third Reference Catalog of Bright Galaxies* (RC3; 23,024 objects) is $23.95. Compare the cost of the RC3 database with the printed version's price: $198. These catalogs are a bargain. Other optional catalogs of interest to deep-sky observers include the *Abell Galaxy Cluster Catalog,* Arp's *Atlas of Peculiar Galaxies, Hubble Atlas of Galaxies, A Catalog of Markarian Galaxies,* Zwicky's *Catalogue of Galaxies and Clusters of Galaxies,* the *Morphological Catalog of Galaxies,* and the remaining 212,819 stars of the SAO star catalog. There are also optional cross-references to *Burnham's Celestial Handbook* and Luginbuhl and Skiff's *Observing Handbook.* HyperSKY includes a data-file editor so that you can add other objects of interest to your sky maps and observing lists.

Surprisingly missing from this list is the *New General Catalogue* (NGC). Some of the data files include NGC objects, but a complete file of NGC objects isn't included. It would be nice if the program were menu-driven rather than keyboard-driven to take advantage of the benefits of the mouse. And there should be a more graceful way to leave the user-option screens than hitting a long series of escapes.

But these complaints are minor. HyperSKY's ability to produce useful sky charts for deep-sky observers is superb. The extensive set of catalogs available to HyperSKY users make this one of the premier programs in amateur astronomy. And you can't beat the price. — *Dave Bruning*

NEW SOFTWARE

***Scope** (version 3.5)*, *Waldee-Wood Astronomical Software, 1750 De Marietta Court #1, San Jose, CA 95126. Phone (408) 993-1976. $39.95. Minimum requirements: IBM-PC compatible computer, 384 KB available memory, and DOS 2.0. Both $3^1/_2$" and $5^1/_4$" diskettes are available. Includes a 5 percent discount coupon for Lumicon filters. A beginner's edition costs $41.95 and includes* Young Person's Guide to Astronomy. *Upgrading to observatory red version for telescope use costs $12.95.*

Interested in the optical performance of your telescope and eyepiece? Scope will tell you the system's magnification, magnitude limit, resolution limit, exit pupil size, estimated visual field size, and the minimum separation of an observable double star. The built-in database contains the specifications for 115 standard eyepieces — or you may enter the data for your eyepiece.

***SkyClock**, Bodhi Software, 2371 N. 63rd Street, Wauwatosa, WI 53213. Phone (414) 453-4123. $79.99. Minimum requirements: IBM-PC compatible computer, DOS 2.0, and 512 KB memory.*

Graphical displays show the planets from Sun- and Earth-centered viewpoints and the positions of the planets above the horizon. SkyClock provides the times of rising and setting for the Sun, Moon, and planets. It can also create an ephemeris for these solar system objects, listing their positions for dates between 4,000 B.C. and A.D. 15,000. ☐

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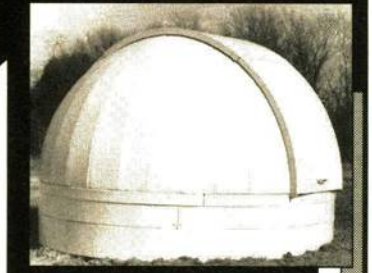

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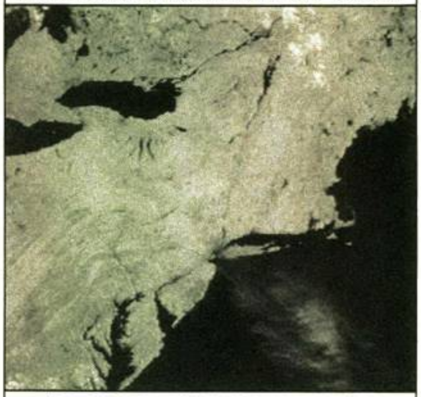

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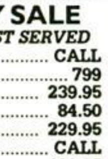
4420 NEWTONIAN



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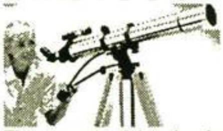

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SCHMIDT-CASSEGRAINS

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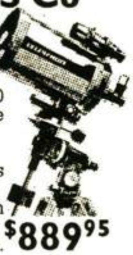

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CLASSIC 8 w/Starbright 1099.95

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FROM RADIO ASTRONOMY TO THE SIZES OF STARS

Boffin, by Robert Hanbury Brown, (Adam Hilger, 1991), ISBN 0-7503-0130-9, 184 pages, hardcover, $35.

Boffin is Hanbury Brown's personal account of the emergence of radar, the blossoming of radio astronomy, and the development of intensity interferometers for measuring the diameters of stars. About one-half of the book details English efforts from 1935 to 1949 to invent a ground-based radar system to detect enemy aircraft and an airborne radar system to detect other aircraft and ships. Two dozen pages describe the early days of radio astronomy after the Second World War, primarily the use of the 218-foot dish at Jodrell Bank with some discussion about the pursuit of quasars and the 250-foot Lovell Telescope.

The story of the development of stellar intensity interferometers unfolds in the last quarter of Hanbury Brown's memoir. This section seems disappointingly short because it is principally this work for which Hanbury Brown is so well known in astronomy. He tells the story from the beginning, the development of quantum optics — the study of photon intensity correlations — by himself and Richard Twiss. He then chronicles the development of stellar intensity interferometers from the war-surplus searchlights pressed into service as telescopes to the pair of 22-foot-diameter telescopes built at Narrabri, Australia.

The Narrabri interferometer measured the diameters of 32 stars, including Sirius and Procyon. But it, like many scopes, eventually was torn down to make way for a new generation. The final chapter describes the closure of the Narrabri Observatory and the development of Sydney University's modernized version of Michelson's stellar interferometer, called SUSI. An epilogue presents Hanbury Brown's unpretentious view of the nature of science after a distinguished lifetime of its study.

Hanbury Brown's story is delightfully spun with many personal reminiscences and colorful tales. And his characterizations of the many people in his stories are candid and lively. (Of Richard Twiss he says, "He had the alarming habit of bursting into song, usually Wagner, whenever he *felt like* it.") This book is thoroughly enjoyable. My biggest disappointment was the emphasis on Hanbury Brown's involvement in inventing radar instead of a greater emphasis on astronomy. Oh yes, *boffin* is British slang for a scientific expert; Hanbury Brown was named a prototype. — *Dave Bruning*

Advanced Amateur Astronomy, by Gerald North, (Edinburgh University Press, 1991), ISBN 0-7486-0253-4, 313 pages, hardcover, $50.

Striving to be a successor to *Observational Astronomy for Amateurs* and the *Amateur Astronomer's Handbook* by J.B. Sidgwick, this book describes observing projects, equipment, and techniques for advanced amateurs. Unfortunately it doesn't measure up to Sidgwick's tomes, not only because it's shorter but also because it too often replaces information about observing projects and techniques with references to other books and magazines. Basic information, such as the accurate polar alignment of your scope, receives a minimum amount of attention because North tries to be too comprehensive for a book of this size.

The first five chapters describe telescopes and astrophotography. Seven chapters systematically describe observing programs and techniques for the Moon, planets, comets and asteroids, the Sun, stars, and galaxies. The remaining four chapters describe radio astronomy, photometry, spectroscopy, and additional sources of information.

The chapters on spectroscopy and photometry highlight this book's flaws as an amateur handbook. Instead of practical information on how to build a spectrometer and what to do with it, North describes the theory of electromagnetic radiation and how spectrometers work. The chapter on photometry describes microdensitometers and photomultiplier tubes rather than the more common silicon diode photometers and CCDs used by amateurs today. (Visual methods are described briefly.) A block diagram of a photometry system appears but is insufficient to use in building a photometer. North doesn't describe the common systems of filters or where you can buy them. Nor does he describe how to reduce photometric observations beyond some simple steps.

Too many of the astrophotos, such as the Moon photos, are badly reproduced, giving a poor representation of amateur astrophotography. Also, too

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20 x 80 BAK4 Prism	$605.00	$240.00
Spotting Scope:	**Retail**	**Sale**
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many of the line drawings (for example, the map of Mars and the rings of Saturn) are simple renditions by the author; more complete drawings should accompany the text.

North had a lofty goal — a complete handbook of advanced amateur astronomy. But unless you want a quick sampling of topics in each area of amateur astronomy, you'll be better off buying advanced books about each of those areas. — *Dave Bruning*

General Interest

Astronomical Almanac for the Year 1993, (U.S. Government Printing Office, 1992), hardcover, $27.

This observer's handbook contains tables of the Moon's phases, planetary phenomena, lunar and solar eclipses, times of sunrise and sunset, observatory names and places, and calendar information. Other tables describe lunar, solar, and planetary positions, sizes, and coordinates and the positions of planetary satellites. Listings of bright stars, variable stars, and galaxies complete the volume.

Stars

Binary Stars: A Pictorial Atlas, by Dirk Terrell, J. D. Mukherjee, and R. E. Wilson, (Krieger Publishing Co., 1991), 223 pages, acid-free paper, ISBN 0-89464-041-0, hardcover, $57.50; ISBN 0-89464-698-2, softcover, $42.50.

Computer models depict over 300 stellar systems in this purely pictorial approach to describing close and interacting binaries. Pictures show the binary system at different aspects through one-half of an orbit and the modeled light curves in the ultraviolet, visible, and infrared. Each binary's entry ends with a table listing the orbital and physical data for the system.

Other Books Received

Objective-Prism and Other Surveys, edited by A.G. Davis Philip and Arthur R. Upgren, (L. Davis Press, 1991), ISBN 0-933485-15-8, 200 pages, hardcover, $35.50. Technical symposium.

The Theory of Cosmic Grains, by F. Hoyle and N.C. Wickramasinghe, (Kluwer Academic Publishers, 1991), ISBN 0-7923-1189-2, 307 pages, acid-free paper, hardcover, $75. Graduate-level text.

Nuclei in the Cosmos, edited by H. Oberhummer, (Springer-Verlag, 1991), ISBN 0-387-54198-5, 236 pages, acid-free paper, hardcover, $59. Graduate-level text. ☐

FOR SALE — Quantum Four f/15 Maksutov-Cassegrain telescope with equatorial mount, 1/20 wave, enhanced coatings optics. Impeccable condition. $2,000 or offer. Contact Sol Saul, 3 Theodore Dr., Plainview, NY 11803. Phone (516) 938-3171.

WANTED — A woman from Pennsylvania who responded to a previous ad seeking pen pals omitted her address. Contact Allen Johnston, 7 Rich Hill Crescent Knock, Belfast BT5 6HF, IRELAND.

WANTED — Astronomy books: *Mars and Beyond*, by Willy Ley; *Guide to Mars*, by Patrick Moore; *The Planet Mercury*, by Sandner; *Our Moon*, by Wilkins/Moore. Must be in good condition. Contact Steve Breutzmann, 4481 S. 114th St., Greenfield, WI 53228.

WANTED — Thirty-one-year-old interested in astronomy, archaeology, geology, and *Star Trek* wishes to correspond worldwide with others with similar interests. Contact Twyla Stickelman, P.O. Box 265, Corning, CA 96021.

FOR SALE — Eight-inch, f/8 custom-made reflector, Dobsonian mount, Novak mirror mount and spider, $340. Six-inch f/7 reflector, Dobsonian mount, Novak accessories, $240. Both like new, with eyepieces. Contact Jim Schwartz, 1828 Kingsway Ct., Cincinnati, OH 45230. Phone (513) 232-5906.

WANTED — People interested in forming a new astronomy club in the Ft. Myers and Naples, Florida, area. Contact Paul Atkinson, P.O. Box 2528, Ft. Myers, FL 33902. Phone (813) 275-3561.

WANTED — Photos of home-built observatories for possible use in a forthcoming book. Write for details. Richard Berry, Route 1 Box 58A, Cedar Grove, WI 53013.

WANTED — Small, new astronomy club dedicated to introducing the wonders of space to inexperienced gazers needs 10" parabolic mirror. Contact Ron Rogers, Northern Illinois Stargazers, 1672 Hill Dr., Dixon, IL 61021.

FOR SALE — J. A. Brashear telescope, mahogany tripod, 48" brass main barrel, 4" objective lens, focusing tube 10" closed, eyepieces. Purchase represents contribution to Upper Keys Humane Society. Contact H. E. Sheppard, P.O. Box 680, Tavernier, FL 33070. Phone (305) 852-4318.

WANTED — Donations for a program that works with schools in the southern Chicago metropolitan area. Looking for back issues of ASTRONOMY, *Sky & Telescope*, *Mercury*, *Odyssey*, etc., for resource library. Also old books, mirrors, telescopes, eyepieces, and cash. All donations tax deductible. Contact First Light, c/o Morton College, 3801 S. Central, Cicero, IL 60650. Phone (708) 656-8000, ext. 219.

FOR SALE — Celestron C-6 f/5 tube assembly only, $150. Eight-inch mirror kit, $40. Cave drive 1½", $80. ASTRONOMY Magazine, 1974 through 1990 (missing 7 early years), $150. Contact Mike, (602) 297-2781 evenings (Mountain Time).

FOR SALE — Meade LX5 with standard equipment, moto-dec. and focus, lenses, and more. Custom wood storage/carrying case can double as field table. $1,450 plus shipping. Contact R. Hoyle, 295 Richoux Rd., Ponchatoula, LA 70454. Phone (504) 386-2208 evenings.

WANTED — Video or slides from July 11th Viking Serenade eclipse cruise showing dolphins that appeared after total eclipse ended. Contact William Hughes, (313) 535-5508.

WANTED — Correspondents interested in astronomy and space exploration, especially with exobiology aerospace medicine. Especially people in Nebraska, Colorado, Kansas, South Dakota. Contact Jim Flanagan, UNK College Heights Apts., Apt. B-100, 1701 35th St., Kearney, NE 68847.

WANTED — Beginner needs all back issues of *TELESCOPE MAKING* Magazine. Also plans for Foucault Tester. Contact W. H. Ferguson, 2513 S. Flagler Ave., Flagler Beach, FL 32136.

WANTED — Seventeen-year-old Portuguese male would like to correspond with others about astronomy in Portuguese, Spanish or English. Would also like to form astronomy club. Contact Victor M. Silva Gomes, Rua Cruz de Pau 18, 3º Dr., 4450 Matosinhos, PORTUGAL.

FOR SALE — ASTRONOMY, January 1978 through December 1987 (missing 7 issues from 1978, 1984 and 1985). $113 plus postage. Contact Steve Wilenski, 2517 Eileen Ct., N. Bellmore, NY 11710. Phone (516) 221-1910.

FOR SALE — Six-inch Newtonian with clock drive, 6" solar filter camera adapter, 9mm and 18mm eyepieces, equatorial mount, and accessories shelf. $350. Contact Jeff Wetzel, (313) 783-0129 evenings.

WANTED — Twenty-one-year-old amateur astronomer interested in planetary science/exploration and science-fiction novels seeks correspondence with anyone. Contact Dave Lavelle, 107 Princeton Ave., Clarks Green, PA 18411.

WANTED — Seventeen-year-old amateur astronomer seeks correspondence from people worldwide. Interested in astronomy, physics and social sciences. Contact Valerie Solco, 45 Tirad Pass St., Quezon City, 1100 PHILIPPINES.

FOR SALE — Celestron Astro C-90 telescope, wedge, fork mount, drive, Barlow, diagonal, three oculars, 1¼" visual back, camera mount, 5x24mm finder, five filters, padded case. $565. Contact Troy Bunch, 4100 W. 49th Ave., Denver, CO 80212. Phone (303) 480-1017.

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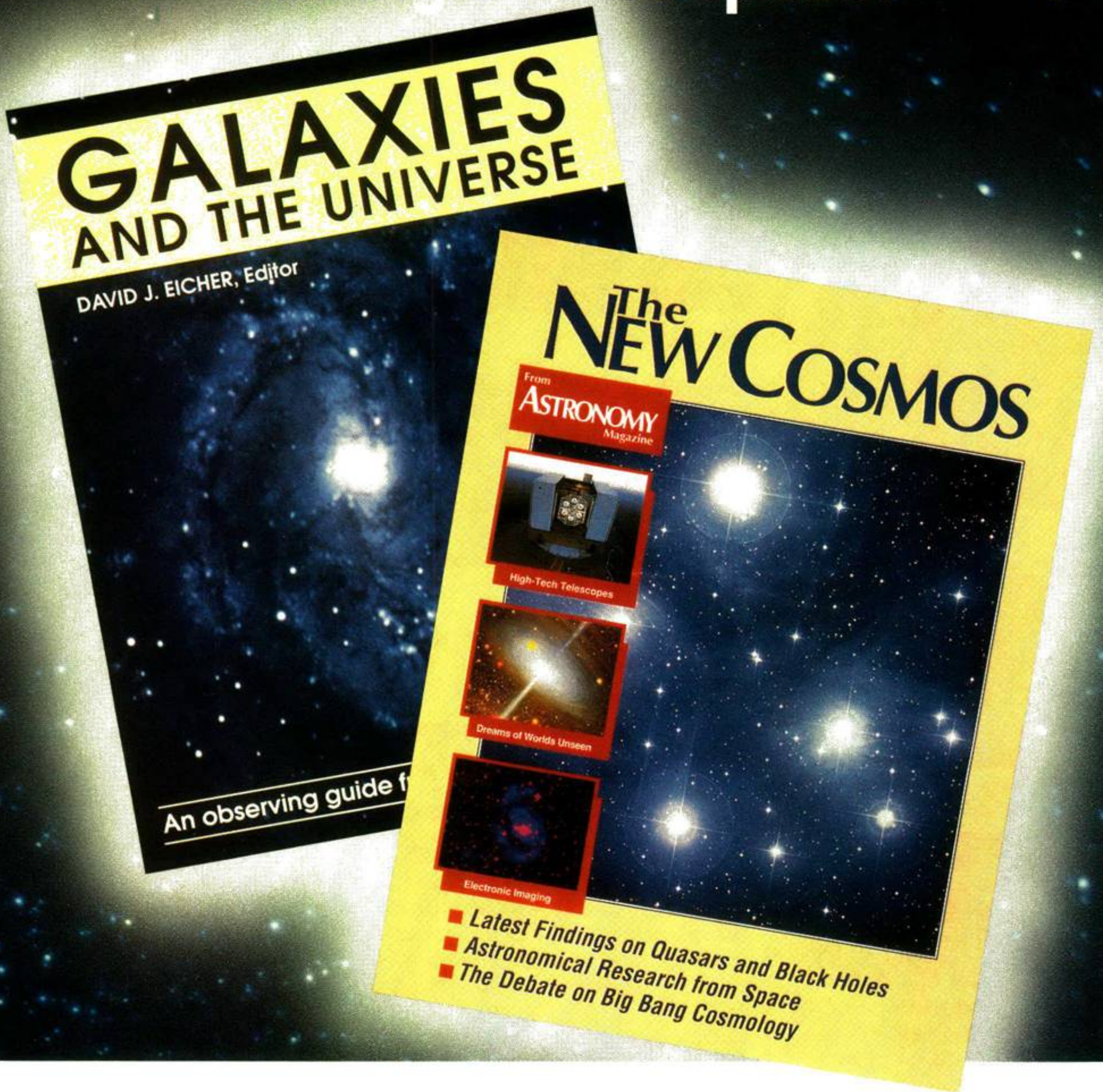
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Colliding Galaxies, by Barry Parker, (Plenum Press, 1990). Describes observations and computer simulations of galaxy collisions and mergers.

"Elliptical Galaxies Forged by Collision," by Karen Hartley, Astronomy, May 1989. How collisions between spiral galaxies may give rise to some elliptical galaxies.

The Grand Illusion (page 44)

The Milky Way by Bart J. and Priscilla F Bok, (Harvard University Press, 1981). Chapter three describes stellar populations and luminosity functions in our Galaxy.

Galactic Astronomy, by Dimitri Mihalas and James Binney, (W. H. Freeman and Company, 1981). A technical book that includes a discussion on the luminosities and surface brightnesses of galaxies.

Build an Astrophoto Platform (page 60)

"A Portable Photographic Platform," by Wallace G. Pursell, Astronomy, July 1987. Instructions for a manually driven camera platform.

Observing the New Mars (page 74)

"Ten Pointers for Mars Observers," Astronomy, July 1988. Valuable observing tips for getting the most out of your telescopic viewing sessions of the Red Planet.

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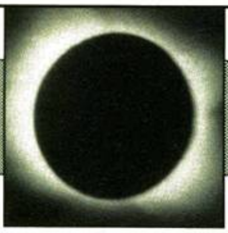

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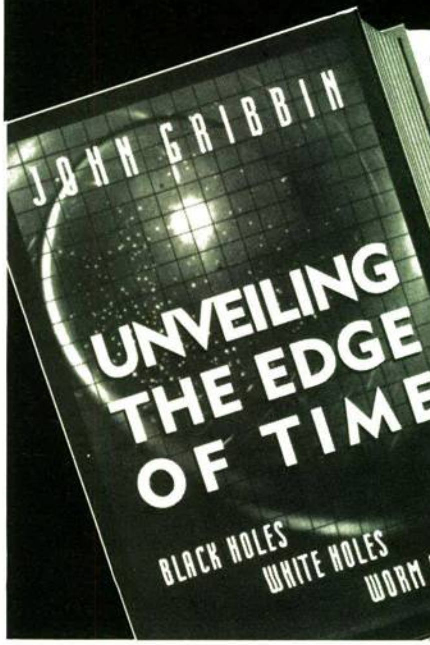

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Optics Workshop for Telescope Makers, Western Washington University, Bellingham, Washington. Sponsored by the Whatcom Association of Celestial Observers. Contact: Kreig McBride, 402 East Horton Road, Bellingham, WA 98226. Phone: (206) 671-1665

November 21
Lake Kissimmee Star Party, Lake Kissimmee State Park, Lake Wales, Florida. Contact: George Aycrigg, 14248 Camp Mack Road, Lake Wales, FL 33853. Phone: (813) 696-1112 (before 2 p.m.), (813) 696-1812 (after 5 p.m.)

December 1-2
Asteroid Safety Conference, Albuquerque, New Mexico. Contact: Safety Research Institute, P. O. Box 9123, Albuquerque, NM 87119-9123. Phone: (505) 255-9801.

December 19
2nd Annual ASV Christmas Star-Be-Que, near Heathcote, Australia. Sponsored by the Astronomical Society of Victoria. Contact: Perry Vlahos, 103A Orrong Cresc., North Caulfield, Victoria 3161 Australia. Phone: (03) 527-8719.

April 5-7, 1993
Second Solar Astronomy Convention, La Paz, Baja California Sur, Mexico. Sponsored by the La Paz Station of the Solar Astronomy Research Center. Contact: Calle La Purisima 119, Colonia Bellavista, Codigo Postal 23050, La Paz, Baja California Sur, Mexico. Phone: 91-682-1-07-32. ☐

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

WANTED — Forty-one-year-old seeks correspondence with amateur astronomers. Interests include space flight and camping and fishing. Contact Terry Hauan, 4001 W. Camelback Rd. #F-37, Phoenix, AZ 85019.

WANTED — Information on telescope engraved, "G. Young & Co., London, Day & Night." Brass with leather binding, breaks into five parts, lenses mounted in brass, extended length approximately 39". Will consider selling. Contact Karen Stanley, P.O. Box 2277, Shallotte, NC 28459. Phone (919) 754-8898 after 5 p.m.

WANTED — Apollo program memorabilia. Contact Andrew T. King, 93 Lenape Trail, Washington, NJ 07882.

WANTED — Trinidad medical doctor seeks correspondence with deep-sky enthusiasts. Contact Dr. Ic. Pariagh, Eastern Main Road, Sangre Grande, Trinidad, WEST INDIES.

WANTED — Thirty-seven-year-old amateur astronomer seeks pen pals to share interest and experiences in astronomy. Other interests include *Star Trek*, computers and ham radio. Contact Mark Estes, 1351 Peapond Rd., Bellmore, NY 11710.

WANTED — Eight-inch or larger telescope to make astronomy accessible to Boy Scouts through special camp programs. Valley Forge Council provides services to over 20,000 scouts. Prefer donations. Contact Bruce Wagner, 324 S. Manor Dr., Media, PA 19063. Phone (215) 494-3102.

FOR SALE — Unitron model 114, 2.4-inch altazimuth refractor. Aperture 60mm, focal length 900mm, focal ratio $^{1}/_{15}$. Unihex with 4 eyepieces: 9mm (100x), 12.5mm (72x), 18mm (50x), 25mm (35x). In wood box, with wood tripod. $550. Phone (414) 421-0128.

WANTED — Twenty-six-year-old interested in astronomy, geography, history, science fiction, politics, and languages seeks European pen pals. Will answer in English or French. Contact Eric Harkness, 57B Goose Hollow Rd., Greenfield Center, NY 12833.

FOR SALE — Questar standard $3^{1}/_{2}$" telescope, unused. Contact George Lauterstein, P.O. Box 1257, Wimberley, TX 78676. Phone (512) 847-3949.

FOR SALE — Meade 2120 LX5 MCOG 10" Oaks solar 2 filter modified extra stable wedge tripod. $1,200. Contact James W. Brimhall, 5509 Brekenridge Dr., Salt Lake City, UT 84117-7308. Phone (801) 262-1481, 5 to 9 p.m. Mountain time.

FOR SALE — Field model Questar $3^{1}/_{2}$. Adaptable to Celestron Super Polaris mount. Several accessories. $1,200 plus shipping. Contact Paul D'Errico, 6001 S. Yosemite St., Apt. J-302, Englewood, CO 80111. Phone (303) 771-7143 evenings and weekends or (303) 741-7004 days.

FOR SALE — Eight-inch f/6 reflector on German equatorial mount, sector drive, $500. $1^{1}/_{4}$" mirror star diagonal, $25. Orion 6mm illuminated reticle eyepiece with moveable reticle, $95. *Sky & Telescope*, July 1984 to December 1991, $110. Contact Dick Lindblom, 2130 Gresham St., Sebring, FL 33872. Phone (813) 655-0131.

WANTED — Astronomers from the greater Bridgewater-Brockton Massachusetts area to get together for astronomy conversation and/or observing sessions. Contact Steve at (508) 697-5281.

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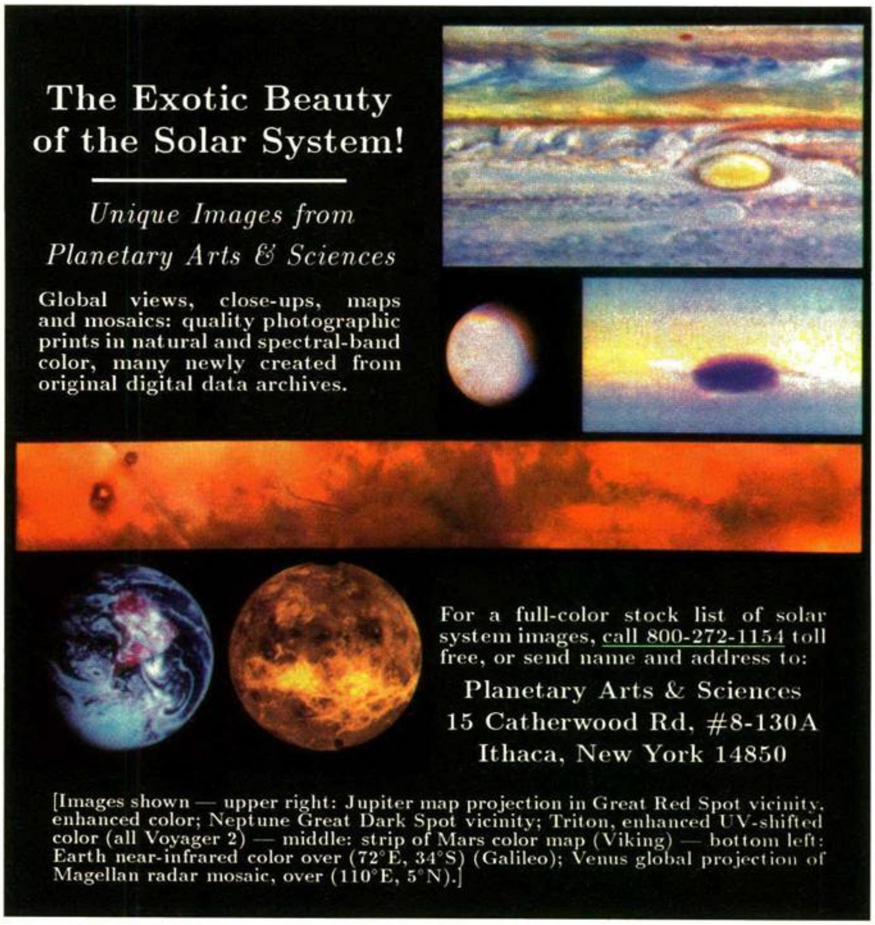

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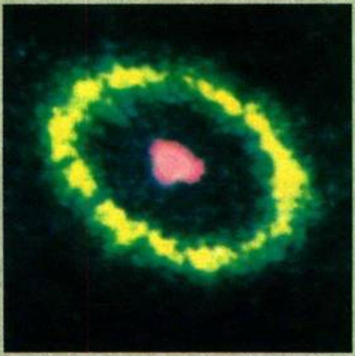
[Images shown — upper right: Jupiter map projection in Great Red Spot vicinity, enhanced color; Neptune Great Dark Spot vicinity; Triton, enhanced UV-shifted color (all Voyager 2) — middle: strip of Mars color map (Viking) — bottom left: Earth near-infrared color over (72°E, 34°S) (Galileo); Venus global projection of Magellan radar mosaic, over (110°E, 5°N).]

COMING IN THE DECEMBER 1992 ISSUE OF

ASTRONOMY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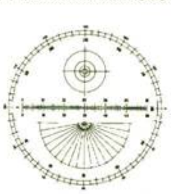

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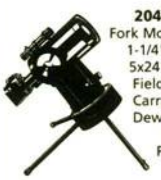

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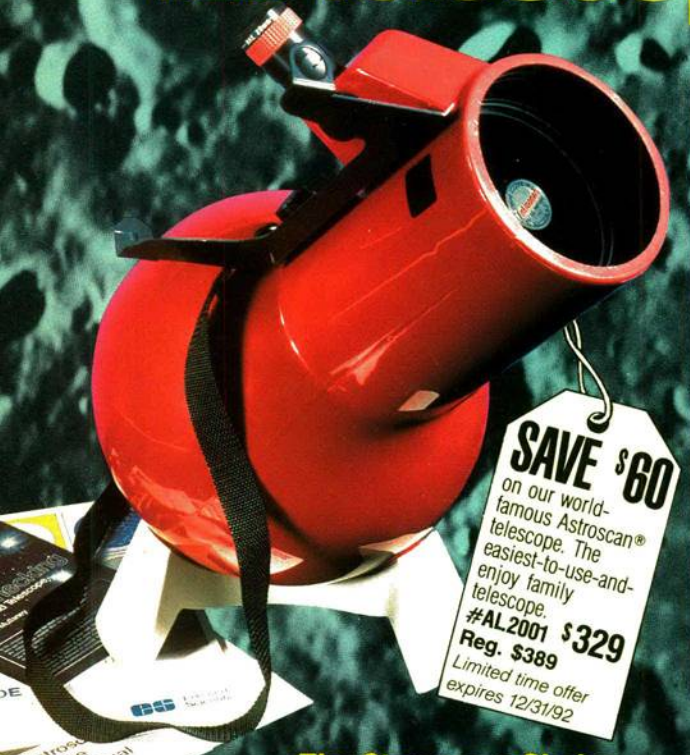
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November 1992

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MODEL	SIZE	FIELD OF VIEW	EYE RELIEF	WEIGHT
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Sport	10x50	7.0°	15mm	29 oz.
Pro	7x50	7.1°	23mm	29 oz.
Pro	10x50	6.5°	15mm	30 oz.
Pro	12x50	5.5°	10mm	29 oz.
Pro	8x56	5.8°	22mm	34 oz.
Pro	9x63	5.0°	21mm	37 oz.
Ultima	7x50	7.0°	20mm	27 oz.
Ultima	10x50	5.0°	21mm	27 oz.
Ultima	8x56	6.1°	21mm	31 oz.
ED	6.5x44	7.3°	20mm	26 oz.
ED	9.5x44	6.0°	18mm	26 oz.
Giant	11x80	4.5°	18mm	80 oz.
Giant	15x80	3.5°	16mm	80 oz.
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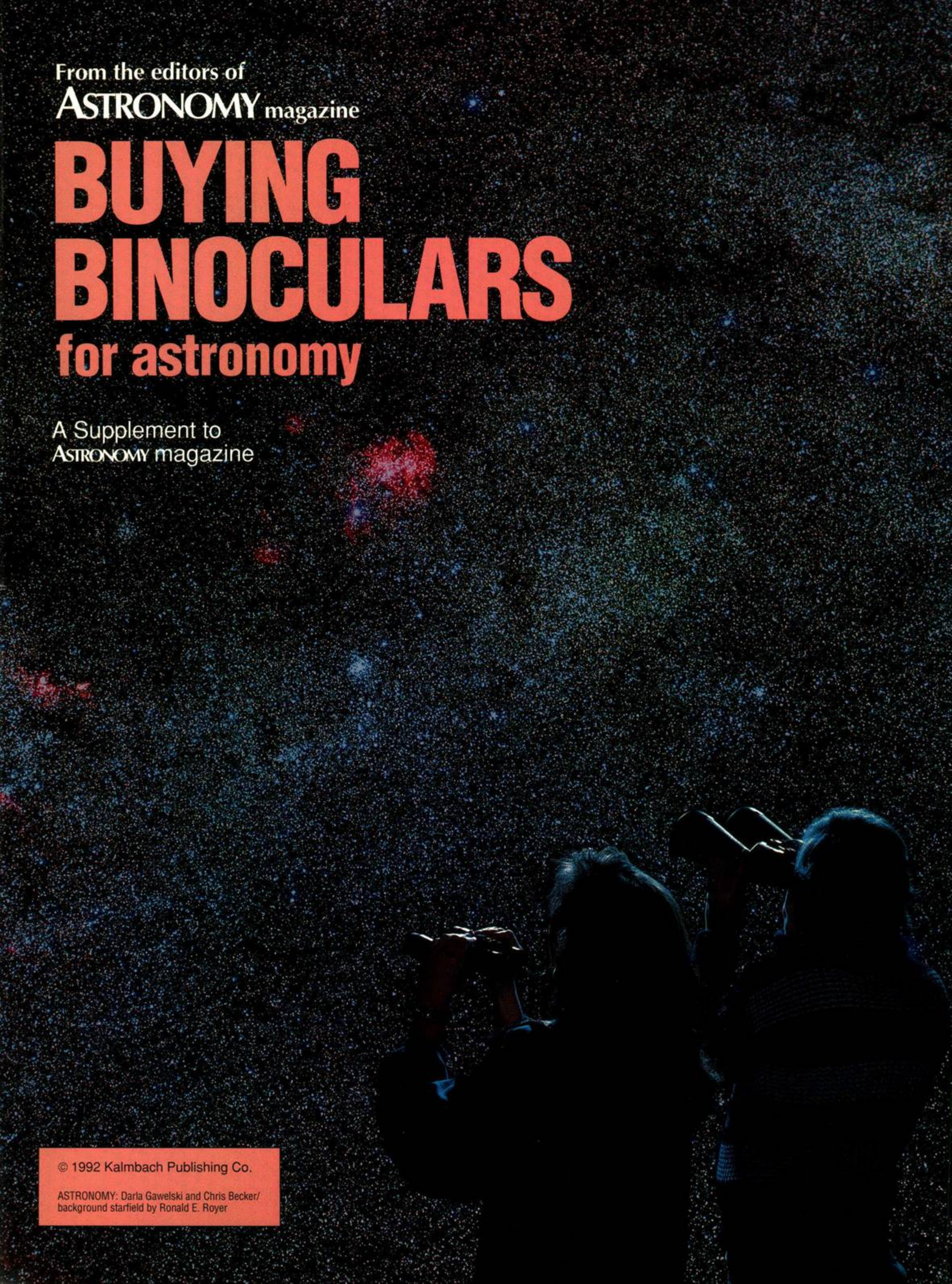
From the editors of
ASTRONOMY magazine

BUYING BINOCULARS for astronomy

A Supplement to
ASTRONOMY magazine



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ASTRONOMY: Darla Gawelski and Chris Becker/
background starfield by Ronald E. Royer

BUYING BINOCULARS

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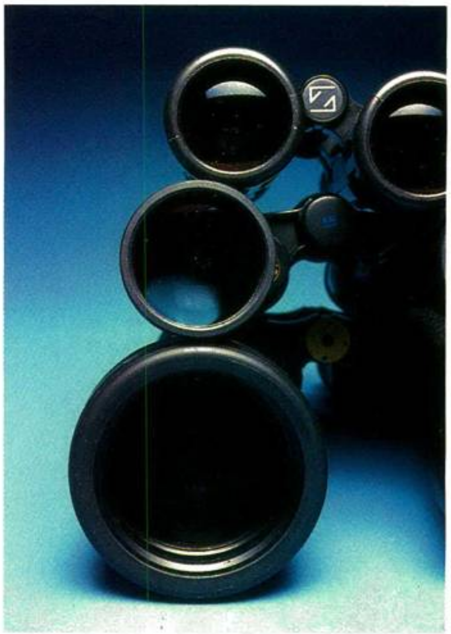
The Binocular Universe



ASTRONOMY: All equipment photos by Darla Gawelski and Chris Becker

THE SIZE OF THE FRONT LENS is the most important characteristic of a binocular for stargazing. Compare these 42mm-, 50mm-, and 70mm-aperture binoculars.

You can watch a ball game through them, follow the flight of an eagle with them, or catch sight of a sailing ship using them. But you can also use binoculars to show you a galaxy two million light-years away.

Binoculars are remarkably capable instruments for exploring the universe. They can reveal craters on the Moon, moons orbiting the planet Jupiter, and Milky Way starfields peppered with uncountable stars.

People tend to think of a telescope as *the* ticket into the hobby of backyard astronomy. Not so. Binoculars are wonderful instruments for anyone starting out in astronomy — their wide field and right-side-up images make finding objects easy. They require no effort to set up — just sling them around your neck and walk outside. Being able to look at a magnified view of the sky with both eyes open is a comfortable and natural way to tour the heavens.

Best of all, binoculars don't cost much. For $100 you can get a pair of binoculars that will provide exemplary performance. For beginners reluctant to make the outlay for a telescope and for cost-conscious parents wanting to encourage a child's interest, purchasing a pair of binoculars is an affordable way to begin a lifetime of stargazing.

Binocular Basics

To determine which binoculars might be best for you, you should become familiar with some basic binocular specifications.

When selecting binoculars for astronomy, the most important characteristic to consider is the *aperture.* Aperture refers to the diameter of the front lenses. The larger the diameter, the brighter the images will be. For astronomy, binoculars should have front lenses at least 40 millimeters (mm) across. Compact 20mm to 35mm binoculars are great for daytime viewing but they don't gather enough light for astronomical use.

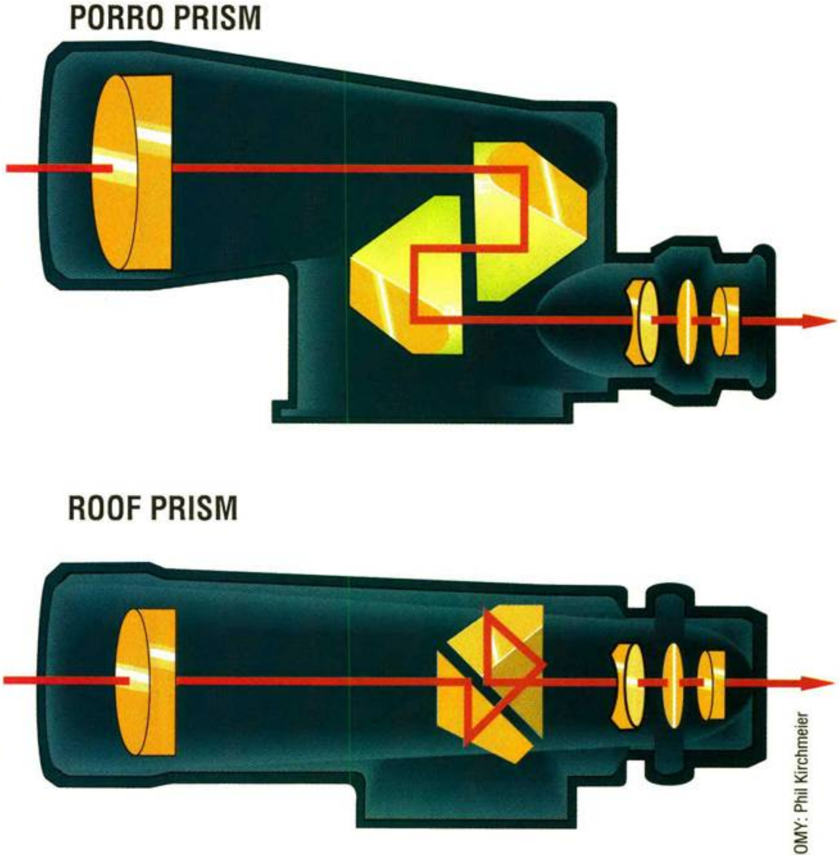
How do you tell what the diameter is? Easy. Every pair is labeled with a figure like 7x50 or 10x50. The second number, in this case the "50," refers to the diameter of the front lenses.

The first figure in the binocular spec, the "7" in 7x50 or 7x42, refers to the *magnification.* A seven-power model, one of the most popular varieties, will bring everything seven times closer. You can also buy 10x, 16x, and even high-power 20x and 30x models.

High power is not the essential feature you might think it is for astronomy. A 7x binocular will work just fine and has advantages over more powerful models we'll outline later on.

You'll see a specification called *exit pupil* in many binocular brochures. It is a measure of the width of the beam of light that comes from the eyepiece. You can determine a model's exit pupil by dividing the binocular's aperture (in mm) by its magnification. For example, a 7x50 model has an exit pupil of 50/7, or 7 mm. *All* 7x50s have exit pupils of 7 mm. All 7x42s have exit pupils of 6 mm, and so on.

You'll find that a lot of binoculars recommended for astronomy have 7mm exit pupils, and for good reason. As your eyes adapt to the darkness of the night, the pupils in your eyes open up to let in more light. The maximum human eyes can dilate to is about 7 mm. Therefore, a binocular that projects a 7mm-wide cone of light into your eyes is making maximum use of the light-gathering ability of your eyes and presents the brightest image possible.



ASTRONOMY: Phil Kirchmeier

BINOCULARS COME IN TWO TYPES. Porro prism binoculars have an N-shape. Straight-through roof prism models are compact but more difficult to make well and often more expensive.

What Can I See?

Binoculars provide a comfortable, clear window to the sky. With them you can see dozens of deep-sky objects such as star clusters, nebulae, and even some bright galaxies, the most distant celestial objects. You can see the moons of Jupiter and watch them change positions from night to night. You can monitor the changing phases of Venus and watch shadows cross lunar features as the Moon waxes and wanes throughout the month.

Other celestial sights just right for binoculars include the Moon suspended in scudding clouds, earthshine on the crescent Moon, the planets Uranus and Neptune, Mercury low in the twilight, bright asteroids, lunar eclipses, and bright comets. Binoculars can provide superb views of Milky Way starfields, the Andromeda Galaxy, and large star clusters such as the Pleiades in the constellation Taurus and the Beehive in Cancer. All told, at least 400 deep-sky objects are within reach of binoculars from a dark site, enough to keep you exploring the sky for several years.

So what can't binoculars do? They cannot show you close-up views of the Moon or details on the planets. If you want to see the clouds of Jupiter or the rings of Saturn, you'll need a telescope. Nor can they resolve small, distant star clusters into individual stars or pick out faint objects such as most galaxies.

CRATERS ON THE MOON

Steve Reed

THE ANDROMEDA GALAXY

John Kerns

THE PLEIADES STAR CLUSTER

Chris Callahan

ASTRONOMY: Darla Gawelski

All binoculars designed for use in low-light conditions have 7mm exit pupils. These include 7x50s, 8x56s, 9x63s, 10x70s, and 11x80s. *In general, these are the best type for astronomy.*

But . . . as you get older, your eyes can no longer open up as much. For people in their 30s the maximum pupil size is about 6 mm. For people over 40 it drops to about 4.5 mm to 5 mm. If your pupils open up only to 5 mm or 6 mm, using a binocular that projects a light cone 7mm wide into your eyes wastes some of the incoming light. Part of the light isn't getting into your eyes and you aren't getting the full benefit of the binocular's light-gathering power.

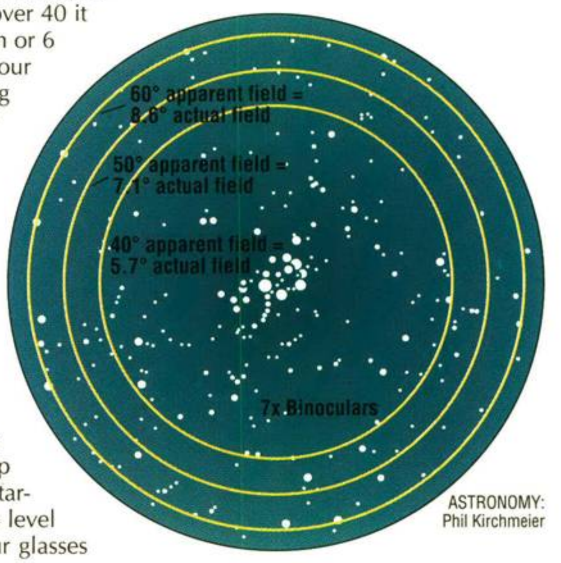
For older viewers then, binoculars with an exit pupil of 5 mm or 6 mm are better. These include popular 7x42 and 10x50 models.

Eye Relief

A specification that manufacturers are paying increased attention to is *eye relief,* a measure of how close you need to place your eyes to the eyepieces to see the entire field of view. The eye-relief figure is important to near-sighted people who wear eyeglasses. Although you can remove your glasses and refocus the binoculars to compensate, doing so is an inconvenience — it's nice to look at a sharp night sky with your glasses on and then quickly flip up the binoculars in front of your glasses without losing sight of your target *and* still see the whole field. In addition, if you suffer from some level of astigmatism in one or both of your eyes, you'll want to keep your glasses on to correct this.

To see the whole field of view with your glasses on you need an eye relief of at least 14 mm to 15 mm, as measured from the tops of the rolled-down eyecups. You can get binoculars that boast eye reliefs of as much as 18 mm to 23 mm. (Binoculars with long eye relief are sometimes called high eyepoint models.)

Models with an eye relief of less than 8 mm or 9 mm probably will be difficult to look through, even for people who don't wear glasses. You'll have to press your eyes up close to the eyepiece to see the entire field, which is a strain for extended viewing and is guaranteed to smear the eyepieces with eyelash grease and dirt.



ASTRONOMY:
Phil Kirchmeier

MOST 7x BINOCULARS have an apparent field of view of about 7°. Models with the widest fields take in over 8° of sky. Narrow-field models show less than 6°.

Field of View

On just about every binocular you'll see a figure like "367 feet @ 1000 yards" or "120 m (@ 1000 m." These numbers refer to how wide a piece of landscape you'll see if that piece of landscape is 1,000 yards (or 1,000 meters) away. This is one way of measuring the field of view of the binoculars.

For viewing the sky, measuring field of view in "feet at 1,000 yards" has little relevance. Instead, astronomers measure field of view in degrees. An angle of one degree (1°) is twice the diameter of the Full Moon.

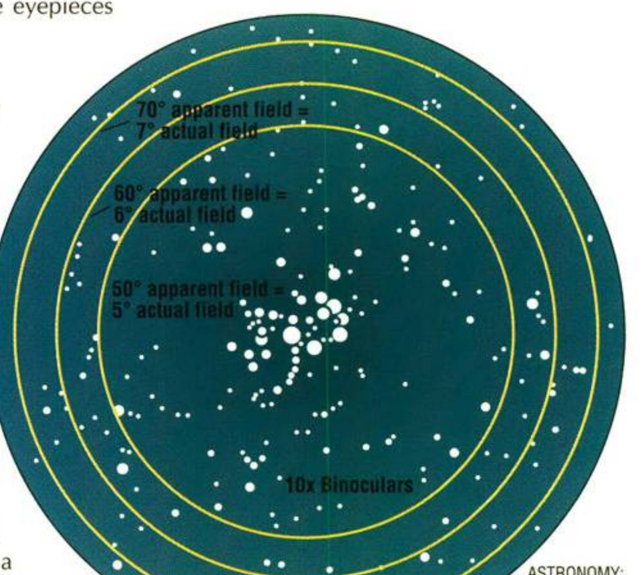
Seven degrees is equal to 14 Full Moon diameters and is a typical field of view for most binoculars. High-power models take in less of the sky (3° to 5°), while wide-angle models take in more (8° to 10°).

To convert from the "feet @ 1000 yards" spec into degrees, divide the feet figure by 52.5. To go from "meters @ 1000 meters," divide the meters figure by 17. For example, a binocular stated as having a field of 367 feet @ 1000 yards has an angular field of 367/52.5, or 7°.

In the tables at the end of the booklet we've listed another field of view, the "apparent field." This is a measure of how wide a circle of light you see when you look through the binoculars. It's a characteristic that comes solely from the type of eyepiece used. Models with small apparent fields (40° to 45°) give the impression you are looking down a narrow tunnel. An apparent field of 50° is the norm. Wide-angle models have apparent fields of 60° to 70°.

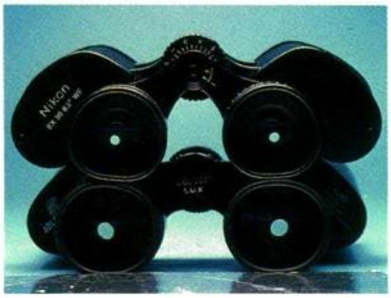
A wide-angle view is dramatic. The tradeoff is that models with wide fields of view usually have star images that look distorted and fuzzy at the edge of the field, detracting from the view. In addition, wide-angle models generally have reduced eye relief.

A relationship exists between the actual and apparent fields of view. Take the apparent field of view (say, 70°) and divide it by the magnification (say, 10x) and



ASTRONOMY:
Phil Kirchmeier

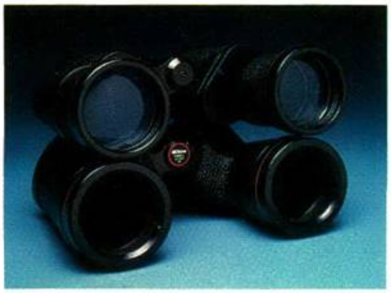
IN A 10x BINOCULAR, objects appear larger. Because of their higher power most 10x binoculars show less sky than 7x models. But some wide-angle 10x binoculars can provide a full 7° field, the same as a 7x model.



EXIT PUPIL is the diameter of the circle of light coming from the eyepiece. Compare the 6x30 at top with the 7x50 at bottom.

EYE RELIEF is the distance from the eyepiece to where the light reaches focus, the point where your eye needs to be.

LARGE EYE LENSES usually indicate long eye relief, a characteristic that aids those viewing with eyeglasses.



MULTICOATED LENSES (bottom) appear dark compared with the more reflective single-layer coated optics (top).

you get the *actual* field of view, in this case 7°. Therefore, if you increase the apparent field, the actual field of view also goes up. But increase the magnification and the actual field goes down.

Prisms

Binoculars contain a complex set of prisms to fold the light path internally and to make the image appear right-side up. Binoculars can be divided into two camps — ones that use porro prisms and ones that use roof prisms. Porro prism models have a zigzag or N-shape. Roof prism models have straight tubes.

Porro prism models generally cost less than the roof prism variety. To work right, roof prisms must be manufactured and mounted to precise tolerances, a more costly procedure. But roof prism models tend to be more compact.

For astronomy, the preference is toward porro prism models. They often have slightly sharper images. But when you train low-cost models on bright stars and planets, you see annoying spikes of light radiating from the object. These diffraction spikes occur because of the way roof prisms split the image in half and then reassemble it. In premium roof prism models, however, this effect is negligible.

With porro prism binoculars, models with prisms made of barium crown glass (abbreviated BaK4) provide a more fully illuminated field. Models with borosilicate glass prisms (BK7) are of a lower grade, but in practice the difference in image brightness is slight.

Coatings

Most binocular optics are coated with at least a single layer of magnesium fluoride. This gives the lenses a bluish tint. The coatings increase light transmission and reduce internal reflections and lens flares, boosting brightness and contrast.

In low-cost models, often only the exterior lens surfaces are coated. These will perform adequately and in inexpensive models are the best you'll find. However, they will be prone to internal reflections and loss of contrast. In such a minimally coated model, as much as 40 percent of the incoming light can fail to make it to your eyes.

Better-grade binoculars have normal coatings on most surfaces but with multilayer coatings on one or more surfaces (usually the two exterior air-to-glass surfaces). In the finest binoculars, multilayer coatings are applied to all lenses and prisms. In these models light loss can be reduced to as little as 5 percent. Multicoated lenses look darker and have a green or dark magenta tint.

Mechanical Features

Most binoculars have a central focusing mechanism that moves both eyepieces at once. These are the most convenient to use. Other binoculars have separate focus adjustments on each eyepiece. These "individual focus" models are better sealed against moisture. They are less convenient to focus, but on the other hand, when stargazing you don't need to be constantly refocusing — everything's at infinity!

All binoculars used at night benefit from being attached to a tripod. To do this, many binoculars are equipped with a 1/4-20 threaded socket for use with commonly available tripod adapters. If the binocular lacks a socket, it may be possible to attach the binocular to a tripod by using an adapter that clamps around the central rod between the two halves or by using a binocular holder that you wrap around the entire body.

Binoculars designed for marine use are waterproof. These use a sealed construction and an interior purged of normal air and filled with dry nitrogen. Waterproofing is not essential but has its place in backyard astronomy — we subject binoculars to cold, dewy night air conditions and then bring them into a warm house where more condensation forms. After enough abuse, moisture and mildew can collect inside the binoculars, clouding the optics and requiring expensive repairs.

Specs You Can Ignore

Binocular brochures often compare models by stating numbers such as "twilight factor" or "relative brightness index." They are intended to provide a means of comparing how well binoculars reveal detail under dim lighting conditions (twilight factor) and the perceived difference in brightness between binoculars (RBI). Because they fail to take into account differences in coatings and optical quality, these factors are of little help in comparing actual performance.

When selecting binoculars, stick with numbers such as aperture, magnification, and the resulting exit pupil size. Coatings are also important — the better the coatings, the brighter the image. For astronomy, those are by far the most important factors.

But I Thought. . .

When shopping for binoculars you'll almost certainly come across a number of misconceptions:

MISCONCEPTION #1

"The bigger the front lens, the wider the field of view."

People mistakenly equate the diameter of the objective lens with how wide a view the binoculars will provide. This leads to the sales pitch that a 50mm model will give you a wider field than a 35mm model.

In fact, the field of view has nothing to do with the lens aperture. The field depends largely on the type of eyepiece used, whether it's a standard field Kellner-style eyepiece (one that uses 3 lens elements) or a wide-angle Erfle-style eyepiece (one that uses 4 or 5 lens elements). Even a 20mm-aperture pocket binocular can have a very wide field of view.

The size of the front aperture affects the brightness of an image — you buy a larger model not for a wider field but to get brighter images, especially useful for astronomy.

MISCONCEPTION #2

"A rubber-armored binocular is waterproof."

Most waterproof binoculars have some sort of armor coating, but this does not mean the reverse is true — armored binoculars are not necessarily waterproof.

MISCONCEPTION #3

"A rubber-armored binocular is shockproof."

Even armored binoculars are susceptible to internal damage from being dropped. Armoring might prevent the body from being dented, but it will not absorb the shock of a large impact. Better-quality binoculars have prisms and lenses more securely mounted than the prisms and lenses in low-cost models. Some premium marine models even boast being shockproof to so many Gs. But all binoculars are fragile. Armored or not, the important components inside are still glass.

WATERPROOF BINOCULARS such as these Nikon, Celestron, and Swift models are often armored, but armored binoculars aren't necessarily waterproof.

MISCONCEPTION #4

"Optical coatings protect the lenses."

The chemical coatings deposited on lenses and prisms do nothing to protect the glass from scratches and dust. If anything, they make caring for the optics more critical since dust and oil can ruin the coatings before they will damage the lens itself. Coatings increase light transmission and contrast. Some also function to block ultraviolet light and to help penetrate haze, but none protect the lens.

To Learn More

To help you get the most out of your binoculars, we recommend the following books.

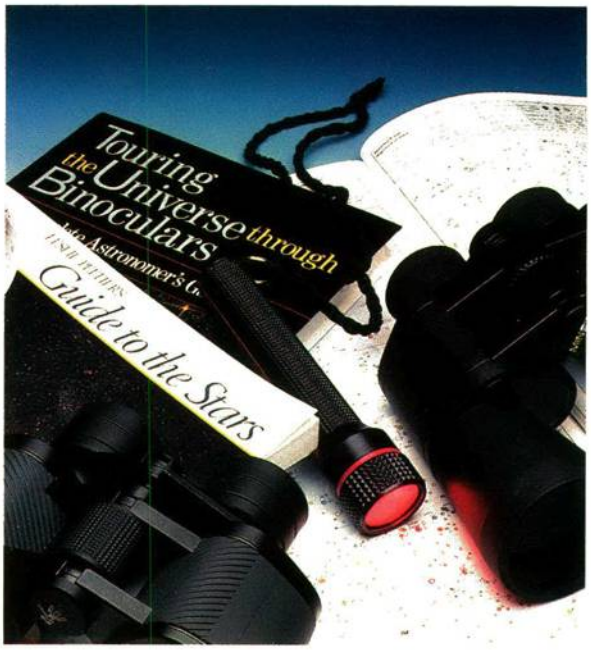
Exploring the Night Sky with Binoculars, by David Chandler, (P.O. Box 309, La Verne, CA 91750). A popular low-cost introduction to the binocular universe.

How to Choose Binoculars, by Alan R. Hale, (C&A Publishing, 800 S. Pacific Coast Hwy., Suite 8-111, P.O. Box 8015-111, Redondo Beach, CA 90277). A good review of binocular selection factors, with extensive tables of binocular models of all sizes.

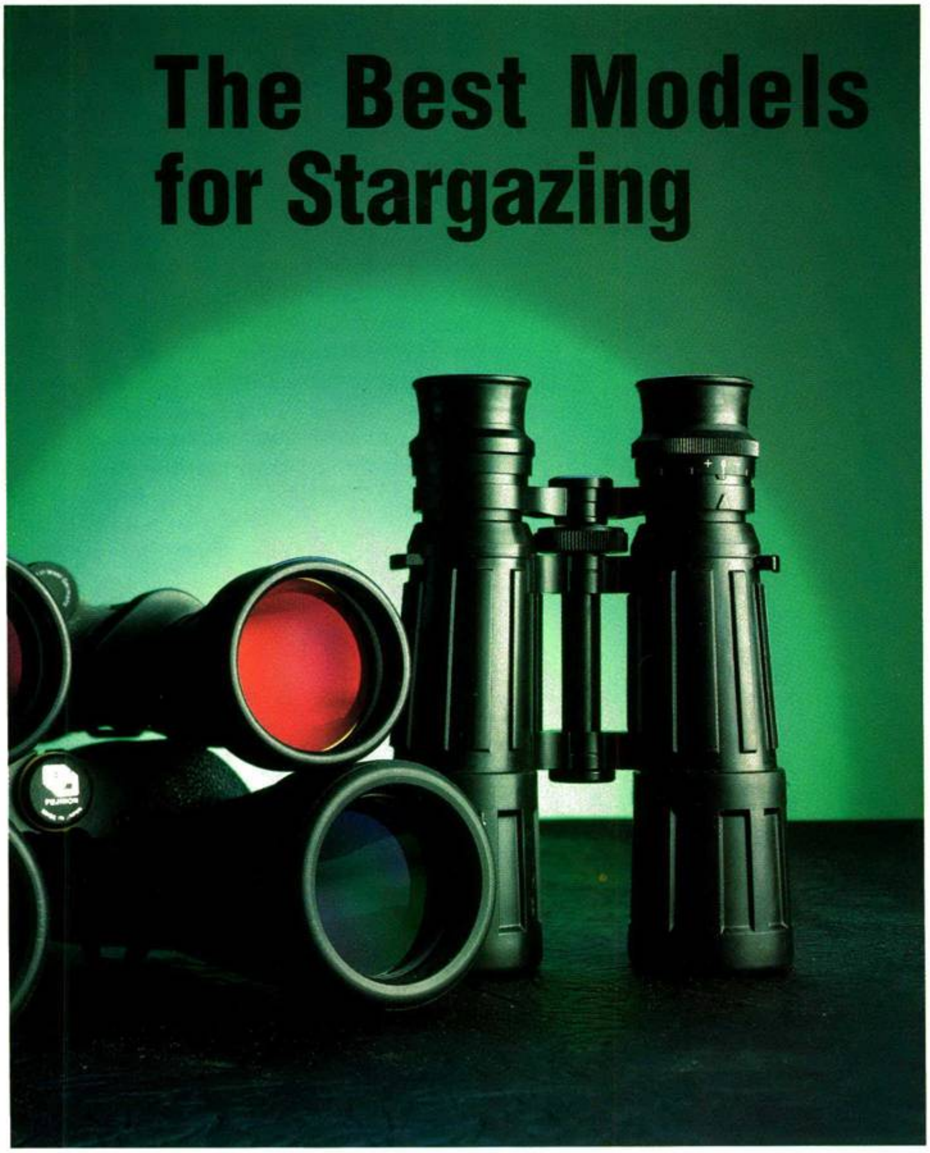
Touring the Universe through Binoculars, by Philip S. Harrington, (John Wiley and Sons, Inc., 1990). Thorough descriptions of 400 deep-sky objects visible in binoculars. Requires a star chart to aid in finding objects.

Leslie Peltier's Guide to the Stars: Exploring the Sky with Binoculars (AstroMedia/Kalmbach Publishing, 1986). An excellent tour of the constellations and deep-sky objects.

The Monthly Sky Guide, by Ian Ridpath and Wil Tirion, (Cambridge University Press, 1987). Star charts for learning the sky along with detailed maps of selected regions to aid in locating binocular objects.


Touring the Universe through Binoculars
Leslie Peltier's Guide to the Stars
The Astronomer's G

The Best Models for Stargazing



Binoculars in the 40mm to 63mm range (the "standard-sized" models) are all hand-holdable and are good for casually scanning about the sky. Giant-sized binoculars with apertures 70 mm or larger require a concerted effort to use (you can mount them on a tripod or a binocular chair) but yield spectacular views, revealing dim objects beyond the reach of smaller models. The two classes of binoculars complement each other and many astronomy buffs find owning one of each a great way to explore the sky.

Standard-Sized Models (40 mm to 63 mm)

7x50. The 7x50 is often considered the best all-round binocular for astronomy. It gives a 7mm exit pupil, has a 6° to 7° field, and is well suited for hand-held use. It can also be used for daytime applications though it is larger than necessary for day use. You have lots of models to select from — there are more 7x50s on the market than any other type of binocular over 35mm in aperture. Because 7x50s are the preferred models for demanding marine use, many 7x50s feature waterproofing and premium optics. Select a 7x50 of any price and you can't go wrong.

10x50. Binoculars in the 10x50 size yield a slightly dimmer sky background than a 7x50 (they have a 5mm exit pupil) but provide greater resolution of lunar features and star clusters. The extra magnification can also help reveal deep-sky objects. Despite their higher power, many 10x50s show the same amount of sky as a 7x50 (roughly 6.5° to 7°). This is because many 10x50s are wide-angle models with apparent fields of 65° to 70°.

The downside is that 10x50s are harder to hold steady, perhaps undermining the very increase in image detail you're seeking. A 10x binocular should be tripod mounted. High-power models also have less eye relief, making them difficult to look through with your glasses on. Binoculars in this class also make higher demands of optical quality than 7x models do. To deliver sharp star images, a 10x50 needs to have good optics. Plan to spend a bit more to get the extra quality when purchasing a high-power binocular.

7x42, 8x40, or 8x42. If you are over age 40, the 5mm to 6mm exit pupil provided by a 7x42, 8x40, or 8x42 may be perfect. Binoculars of this size weigh less than many 7x50s and are also great for daytime viewing and nature spotting. Some can focus on objects as close as a few feet away, a feature useful for birding. If you want an all-purpose binocular, this class can provide it.

You can also find binoculars in this range with wider fields than in the 7x50 size. The extra field of view might be a good tradeoff for the slightly (and the difference is slight) dimmer images.

8x56 and 9x63. These offer a compromise between the convenient 40mm to 50mm models and the giant 70mm and 80mm models. These are specialized night glasses you aren't likely to use as general purpose daytime binoculars. Few manufacturers offer these sizes and those models that are available tend to be expensive, understandable considering the larger lenses and limited production.

10x40 and 10x42. With a 4mm exit pupil, these models can certainly be used for astronomy but are designed primarily for birders (among others) looking for a high-power model for use under daytime conditions. If that is your primary purpose, with stargazing a sidelight, then a 10x40 is a good choice, especially one of the premium roof prism models.

Giant-Sized Models (70mm and larger)

10x70 and 16x70. There aren't a lot to pick from in these sizes but those that

Models to Avoid

Zoom Binoculars

These generally have narrow fields of view and optics that lack sharpness in the center and edge of the field.

Fixed-Focus Binoculars

These models are preset to provide focused images for people with perfect vision but only when aimed at a moderate distance. When aimed at the stars, fixed-focus binoculars provide blurry images even when used with corrective glasses. Because the ability to focus precisely is essential for obtaining pinpoint star images, fixed-focus binoculars are unsuitable for astronomy.

are available are ideal for astronomy. They give 4° to 5° fields and will provide views unlike any you can get with smaller binoculars or with any telescope. The three-dimensional appearance of the sky and the ease of viewing with both eyes, combined with the light-gathering power of a small telescope, make using a giant binocular (70mm or 80mm) a joy.

But these models must be tripod-mounted. Another caveat is that, tripod or no tripod, looking high in the sky is a strain on the neck. For getting the most out of this style of binocular, one of the new binocular stands or chairs available to amateur astronomers from a number of small entrepreneurs is a welcome accessory but one that may cost as much as the binoculars themselves.

11x80 and 15x80. These give a tad more light-gathering power but are slightly larger and sometimes heavier still. But when you're in this league a few extra ounces won't make much difference.

You'll find a lot of similarity among the various brands of 80mm binoculars. Most of the 11x80s have 4.5° fields. Most come with a bracket for attaching the binoculars to a tripod. Some models have a reinforcement bridge between the two big lenses, which helps keep the two optical trains in line. You *will*, however, find differences in coatings and armoring and sometimes big differences in price.

As with the 70mm models, the 15x and 16x versions will better resolve deep-sky objects such as star clusters but have dimmer fields and decreased eye relief compared with the 7mm-exit-pupil versions.

20x80 and higher powers. Avoid the temptation of *extremely* high powers. Binoculars are available in 20x and even 30x sizes. For specialized applications during the day (ship spotting, wildlife monitoring) these can be useful. But for astronomy, the fields of view are too narrow and the images too dim for finding objects easily. This size won't provide the type of breathtaking, wide-angle view binoculars are best at. For high-powered inspection of celestial objects, it's best to turn to a telescope.

14x100, 20x100, 25x100, and larger. These are massive binoculars and are essentially twin telescopes. They are for the deep-sky enthusiast. Well-heeled binocular addicts can even purchase 6-inch (150mm) binoculars.

A recommendation here is that you consider models with 45°-angle eyepieces. They make viewing through the binoculars easier when they are aimed up. However, if you intend to mount these giants on some sort of binocular chair that suspends the binoculars in front of your eyes no matter where you look, the angled eyepieces may not be a consideration.

For More Information

For product literature and the names of dealers nearest you, call these binocular manufacturers:

aus Jena: c/o Europtik (717) 347-6049 (Central Time)
Brunton Company: (307) 856-6559 (Mountain)
Bushnell/Bausch and Lomb: (800) 255-6366 (Central)
Carl Zeiss Optical, Inc.: (800) 338-2984 (Eastern)
Carton Optics (Adlerblick): c/o TAD International (408) 245-4818 (Pacific)
Celestron & Vixen: (310) 328-9560 (Pacific)
Edmund Scientific: (609) 573-6250 (Eastern)
Fujinon Inc.: (201) 633-5600 (Eastern)
Jason Empire, Inc.: (800) 255-6366 (Central)
Leica: (201) 767-7500 (Eastern)
Leupold and Stevens, Inc.: (503) 646-9171 (Pacific)
Meade Instruments Corporation: (714) 556-2291 (Pacific)
Minolta Corporation: (201) 934-5437 (Eastern)
Mirador Optical Corp.: (213) 821-5587 (Pacific)
Miyauchi: c/o Land, Sea, and Sky (713) 529-3551 (Central)
Nikon Inc.: (800) 645-6687 (Eastern)
Optolyth USA: (503) 628-0246 (Pacific)
Parks Optical: (805) 522-6722 (Pacific)
Pentax Corporation: (303) 799-8000 (Mountain)
Redfield Inc.: (303) 757-6411 (Mountain)
Selsi Company, Inc.: (201) 935-0388 (Eastern)
Simmons Outdoor Corp.: (305) 252-0477 (Eastern)
Steiner Binoculars: (609) 854-2424 (Eastern)
Swarovski Optik: (800) 426-3089 (Eastern)
Swift Instruments, Inc.: (617) 436-2960 (Eastern)
Tasco: (305) 591-3670 (Eastern)
Unitron: (516) 589-6666 (Eastern)
University Optics, Inc.: (313) 665-3575 (Central)
Vivitar Corporation: (213) 870-0181 (Pacific)

7x42 BINOCULARS are popular all-purpose models that are smaller and lighter than most 7x50s.

7x50 BINOCULARS are the most popular for astronomy. They come in all prices from less than $100 up to $1,200.

8x56 BINOCULARS are not common but offer large aperture and a 7mm exit pupil in a hand-holdable package.

10x70 AND 11x80 BINOCULARS are ideal for astronomy but can be expensive and too heavy to hand-hold for any length of time.

Check It Out

Here are some simple tests you can perform when inspecting binoculars in a store.

Type of prisms. Hold the binoculars away from your eyes. If the circle of light you see through the eyepieces appears to have dark, squared-off edges, the prisms are the BK7 variety. The preferred BaK4 type will produce an evenly illuminated disk of light.

Coatings. Look down the front lenses and check the reflections from lights or windows. If you see lots of white reflections, the optics are not multicoated or perhaps not coated at all. The reflections off multicoated lenses will look green or magenta and should appear quite dim. Looking into a fully multicoated binocular should be like looking into a dark hole.

Collimation. Look through the binoculars with a hand covering one of the lenses. Now uncover the lens. Do the images presented by the two optical systems fuse together instantly, or do you have to force the images together? If the two sets of optics are misaligned, looking through them is like looking cross-eyed. The result? Eye strain and headaches.

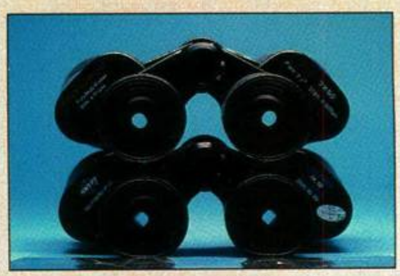
On-axis sharpness. To compare which binocular provides the sharpest image, focus on a distant subject with fine detail. But be sure both eyepieces are sharply focused for your eyes first — center-focus binoculars have an adjustment on the right eyepiece to compensate for the difference in focus between your two eyes. In addition, if you remove your eyeglasses to view, will the binoculars still focus when aimed at infinity? Some models barely reach focus when used by near-sighted observers.

Edge sharpness. Move the same detailed subject to the edge of the field. Does it become blurry? And at what point? Better binoculars will provide sharp images closer to the edge of the field. But almost all models exhibit some loss of sharpness at the very edge.

Eye relief. If you wear glasses for seeing at a distance, can you keep them on and still see the entire field of view?

Focus stability. Press your hand down onto the eyepiece cups. If the focus shifts under light pressure, the binoculars will be susceptible to sliding out of focus accidentally.

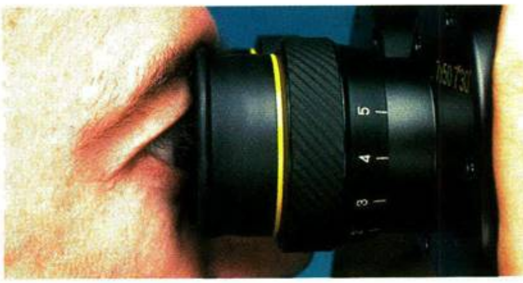
Handling. Unlike telescopes, you practically wear binoculars. How comfortable they feel is something only you can decide. Do the binoculars rest comfortably in your hands? Can you hold it and adjust focus easily when you have gloves on? If the binoculars have individual focus eyepieces, are they easy to adjust? Keep in mind that some of your observing will be done on cool nights when moving parts lubricated with grease may become stiff.

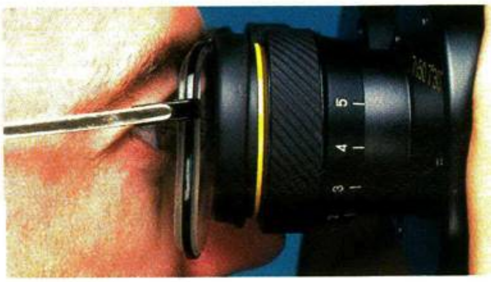


LOWER-COST BK7 PRISMS reveal themselves (bottom) by the squared-off appearance of the circle of light in the eyepiece.

MULTICOATINGS have a greenish or magenta tint and exhibit only dim reflections of light sources.

PRESSING DOWN on the eyepiece bridge reveals whether the focus will shift inadvertently under normal use.





EYECUPS that roll down are essential if you wish to view with your eyeglasses on and see the whole field.

Tradeoffs

Optimizing one binocular trait often means sacrificing another. For example:

Field of view vs. edge sharpness. Binoculars with very wide fields of view invariably have aberrations at the edge of the field that distort star images.

Magnification vs. center sharpness. Images may not be as sharp in high-power binoculars because "on-axis" aberrations become more apparent in these models.

Field of view vs. eye relief. Wide-angle eyepieces usually have reduced eye relief; long eye relief often means sacrificing field of view.

Aperture vs. weight. The bigger the aperture of the front lens, the brighter the image but the heavier the binocular.

Using the Tables

The tables that follow list more than 150 models of binoculars suitable for astronomy. In the 42mm size, we have listed just 7x models (ones with exit pupils of 6 mm). However, many manufacturers have 8x, 9x, and 10x models as well.

Aperture. The tables group binoculars in order of increasing aperture. Within each aperture class, models are listed in order of increasing price.

Field of View. Actual Field of View (FOV) is a measure of how much sky you'll see when you look through that model. It's measured in degrees (°). Apparent FOV measures how wide a circle of light you see when you look through the binoculars. Divide *apparent* field by the magnification to get the *actual* field.

Eye Relief. If you want to keep your glasses on when using binoculars, you'll want binoculars with an eye relief of at least 14 mm.

Coatings. Models with only single-layer coatings applied to one or more of the surfaces are labeled "C." Models with multilayer coatings on one or more surfaces are "MC." The best grade is fully multicoated, "FMC" — all optical surfaces have been multicoated.

Prisms. If the binocular has porro prisms (as opposed to roof prisms) we've indicated whether they are made of BaK4 or BK7 glass.

Type of Focusing. We've indicated whether the binocular has a single center-focus (CF) mechanism or individual focus (IF) eyepieces.

Roll-Down Eyecups. A binocular that lacks roll-down or retractable eye cups may not be usable with eyeglasses.

Tripod Socket. Not all binoculars have a 1/4-20 threaded socket for attaching a tripod adapter bracket. Other types of adapters are available to mount binoculars that lack sockets.

Armoring. Models with a soft leatherette finish over part of the body (to aid in gripping the binocular) are indicated as "partial." Binoculars with a full body covering of textured rubber are indicated as armored. For models that are available in both standard and armored versions, armoring is listed as an "option."

Waterproofing. Models listed as "partial" are water-resistant, sometimes referred to as splashproof or fogproof. They will not survive a full immersion.

Case. HV = hard vinyl, HL = hard leather, SV = soft vinyl, and SL = soft leather. If the type of case isn't known, it is indicated as "incl." (included).

Warranty. Warranties vary but none cover accidental breakage or damage from misuse. Binoculars are twin precision-aligned sets of optics and must be handled with care, but even the least expensive of pairs can last a lifetime.

Weight. Lightweight models (17 to 30 oz.) will be less of a burden around your neck during a night's viewing. Heavyweights (50 to 80 oz.) are good only for occasional quick glances hand-held and must be tripod-mounted for lengthy viewing.

Price. Most prices in the lists are typical retail prices at binocular mail-order dealers as of spring 1992. Those marked with an asterisk (*) are the manufacturer's suggested list prices; these models may be available for less at many dealers. All prices are subject to change and may vary from dealer to dealer.

To help you select a binocular for your budget we've listed models in order of increasing price. The jump from the $100-or-less price league to the $200 to $400 range nets you a big increase in optical quality (better coatings and prisms, and usually sharper images). Models also become more solidly constructed and often boast a wide field while maintaining a comfortable eye relief.

Above $400 or so, the increases in price net you smaller and smaller improvements: wider fields with generous eye relief, super coatings that produce brighter images and reduce lens flare to zero, and more pinpoint images at the edge of the field — all enclosed in a rugged package designed to better withstand bumps and knocks.

However, don't be intimidated by the high-priced models. Even a low-priced binocular can provide excellent performance and years of satisfying views of the wonders of the night sky.

FOCUSING can be with individual adjustments on each eyepiece (left) or with one central focus knob (right).

ARMORING can vary from none at all (left) to a non-slip vinyl covering (middle two) to a thick rubber coating (right).

THE WEIGHT of 7x50 models can range from featherweight 23-oz. binoculars to hefty 50-oz. models.

TRIPOD ATTACHMENT can be with an L-bracket that screws onto the binocular (left), with an adapter that clamps over the bridge (middle), or with a wrap-around holder.

Manufacturer	Model	Actual FOV (°)	Apparent FOV (°)	Eye Relief (mm)	Coatings	Prisms	Focus Type	Roll Down Cups	Tripod Socket	Armored	Water-proof	Case	Warranty (years)	Weight (oz.)	Retail
7x42 MODELS															
Carton	Adlerblick	6.5	46	22	FMC	BaK4	CF	√	√	partial	—	HV	20	21	$180
Fujinon	Series 4000 DCF	6.5	46	21	MC	Roof	CF	√	√	—	—	incl.	Life	19	$190
Tasco	Futura LE	7.0	49	18	C	BK7	CF	√	—	√	—	SV	Life	22	$190*
Swift	7.5x42 Osprey BCF	7.0	53	15	C	BaK4	CF	√	√	√	—	—	Life	29	$190
Meade	High Eyepoint	6.5	46	21	MC	Roof	CF	√	—	√	—	SV	Life	22	$200
Swift	Ultralite ZCF	6.5	46	17	MC	BaK4	CF	√	√	partial	—	?	Life	20	$210
Mirador	7x40 BCF A-Series	6.6	46	20	MC	BaK4	CF	√	√	—	partial	incl.	Life	23	$220
Celestron	Ultima	7.0	49	23	FMC	BaK4	CF	√	√	partial	—	HV	Life	22	$220
Minolta	Weathermatic	9.3	65	6	MC	Roof	CF	√	√	√	√	HV	25	29	$250
Brunton	Eterna	9.3	65	20	FMC	BaK4	CF	√	—	√	—	SV	Life	28	$280*
Unitron	Pro #111A	6.6	46	?	MC	BaK4	CF	√	√	—	—	incl.	25	22	$285*
Mirador	ZCF Y-Series	6.6	46	22	MC	BaK4	CF	√	√	—	—	HV	Life	22	$340*
Swarovski	M Traditional	6.5	46	12	FMC	BaK4	CF	√	—	option	√	—	Life	23	$420
Optolyth	Alpin	6.6	46	16	FMC	BaK4	CF	√	—	√	—	SL	30	17	$460
Swarovski	SL Series	6.5	46	11	FMC	BaK4	CF	—	—	√	√	—	Life	31	$550
aus Jena	7x40 BGA Safari	7.5	53	20	FMC	Roof	IF	√	—	√	partial	—	Life	34	$725*
Optolyth	Touring	8.0	56	10	FMC	Roof	CF	√	—	√	—	SL	30	30	$730
Celestron	6.5x44 ED Series	7.5	49	20	FMC	BaK4	CF	√	√	√	—	SV	Life	26	$790*
Swarovski	SLC	8.0	56	?	FMC	Roof	CF	√	√	√	√	—	Life	31	$925*
Zeiss	B/GA T* Dialyt	8.6	60	18	FMC	Roof	CF	√	—	√	√	SL	30	28	$1,030
Leica	BA Ultra	8.0	56	17	FMC	Roof	CF	√	—	√	√	incl.	Life	31	$1,200
7x50 MODELS															
Vivitar	#634132	7.0	49	?	C	BK7	CF	√	—	—	—	incl.	10	23	$50
Simmons	WA Red Line	6.8	48	12	C	BK7	CF	√	—	—	—	HV	1	37	$70*
Jason	Mercury #1112F	7.0	49	13	C	BK7	CF	√	—	—	—	SV	Life	28	$80*
Orion	Observer	7.0	49	10	C	BK7	CF	—	√	partial	—	HV	2	27	$80
Swift	Aerolite ZCF	7.1	50	14	C	BK7	CF	√	—	—	—	HV	5	38	$90*
Tasco	Standard #2022	7.0	49	?	C	BK7	CF	√	—	—	—	—	Life	27	$90*
Jason	All Terrain #123	7.0	49	16	C	BK7	CF	√	—	partial	—	SV	Life	27	$95*
Minolta	Standard	7.8	54	18	MC	BaK4	CF	√	√	√	—	HV	25	35	$100
Orion	Explorer	6.8	48	17	MC	BaK4	CF	√	—	partial	—	HV	5	25	$100
Selsi	Rubberized #46	7.0	49	15	C	BK7	CF	√	—	√	—	HV	Life	26	$105*
Unitron	Unifocus #102U	6.5	45	14	C	BK7	CF	√	—	—	—	HV	25	24	$105*
Bushnell	Ensign #13-7551	7.0	49	?	C	BK7	CF	√	—	√	—	SV	Life	29	$120*
Celestron	Sport	7.0	49	10	C	BK7	CF	—	√	partial	—	HV	Life	29	$130*
Nikon	Stayfocus Plus	6.2	43	16	MC	BaK4	CF	√	—	partial	—	incl.	25	30	$130
Swift	Swift Focus	8.0	56	17	C	BK7	CF	√	—	√	—	HV	5	32	$140*
Celestron	Pro	7.1	50	19	FMC	BaK4	CF	√	√	√	—	HV	Life	29	$150
Pentax	PCF	7.1	50	20	MC	BaK4	CF	√	√	partial	—	SL	Life	32	$150
Simmons	Rubber-Armored	6.5	45	15	C	BK7	CF	√	—	√	—	HV	Life	28	$150*
Selsi	Standard #108	7.0	49	18	C	BK7	CF	√	√	—	—	HV	Life	33	$160*
Unitron	High Eyepoint #102LE	6.8	48	17	C	BK7	CF	√	—	partial	—	HV	25	25	$165*
Mirador	BCF Series	7.2	50	?	C	BaK4	CF	√	√	—	—	HV	Life	25	$170*
Swift	Dolphin ZCF	7.1	50	18	C	BK7	CF	√	√	partial	—	HV	Life	29	$170*
Tasco	Armored #222YRZ	7.0	49	?	C	BK7	CF	√	—	√	—	—	Life	33	$170*
Unitron	Armored #107BS	7.0	49	15	C	BK7	CF	√	√	partial	—	HV	25	26	$175*
Swift	Sea Wolf BCF	7.1	50	19	C	BaK4	CF	√	√	√	√	—	Life	31	$180
Vivitar	Series 1	7.5	53	?	FMC	BaK4	CF	√	√	√	√	incl.	30	40	$180
Tasco	Futura LE	6.8	48	17	C	BK7	CF	√	—	√	—	SV	Life	25	$190*
Minolta	Weathermatic	7.1	50	15	MC	BaK4	CF	√	√	√	√	HV	25	35	$200
Swift	Skipper BCF	7.3	51	16	C	BaK4	CF	√	√	—	—	HV	Life	30	$240*
Nikon	Windjammer	6.2	43	16	MC	BaK4	IF	√	—	√	√	SV	25	37	$270
Fujinon	AR Nautilus	7.5	53	16	FMC	BaK4	IF	√	√	√	√	—	Life	46	$275
Carton	MC Adlerblick	7.0	49	25	FMC	BaK4	CF	√	√	partial	—	HV	20	27	$280
Celestron	Ultima	7.0	49	17	FMC	BaK4	CF	√	√	partial	—	HV	Life	26	$280
Tasco	Waterproof #322BW	7.0	49	13	C	BaK4	IF	√	√	—	√	SV	Life	34	$290*
Edmund	Waterproof Marine	7.5	53	?	C	BK7	CF	√	√	√	√	HV	1	37	$300
Fujinon	MT-SX Poseidon	7.5	53	12	FMC	BaK4	IF	√	√	option	√	HV	Life	45	$370

Manufacturer	Model	Actual FOV (°)	Apparent FOV (°)	Eye Relief (mm)	Coatings	Prisms	Focus Type	Roll Down Cups	Tripod Socket	Armored	Water-proof	Case	Warranty (years)	Weight (oz.)	Retail
Swift	Sea Hawk BIF	7.5	53	19	C	BaK4	IF	√	√	√	√	—	Life	40	$375*
Nikon	Seafarer II	7.3	51	15	FMC	BaK4	IF	√	—	√	√	incl.	25	61	$410
Bushnell	Marine #12-8755	7.5	53	19	C	BaK4	IF	√	√	√	√	SV	Life	39	$420*
Optolyth	Alpin	5.8	41	22	FMC	BaK4	CF	√	—	√	—	SL	30	23	$490
Fujinon	FMT-SX Polaris	7.3	51	23	FMC	BaK4	IF	√	√	option	√	HV	Life	52	$500
Steiner	G Military	7.0	49	21	MC	BK7	IF	√	option	√	√	—	5	37	$500
Mirador	BCF EXL-Series	7.3	51	13	MC	BaK4	CF	√	√	—	—	incl.	Life	46	$550*
Swarovski	SL Series	7.1	50	11	FMC	BaK4	CF	—	—	√	√	—	Life	41	$570
aus Jena	Binoctar	7.3	51	?	FMC	BaK4	CF	√	√	option	—	HL	Life	35	$590*
Swift	Storm King BIF	7.3	51	16	C	BaK4	IF	√	√	√	√	HV	Life	52	$600*
Nikon	SP-IF Prostar	7.3	51	15	FMC	BaK4	IF	√	—	—	√	HV	25	52	$650
Steiner	Whitetail	7.0	49	21	FMC	BaK4	IF	√	option	√	√	—	5	37	$700
Unitron	Marine #160B	7.3	53	17	C	BaK4	IF	√	√	√	√	HV	25	51	$725*
aus Jena	B Nobilem	7.6	53	17	FMC	BaK4	CF	√	√	option	partial	HL	Life	37	$740*
aus Jena	8x50 B Octarem	7.2	58	10	FMC	BaK4	CF	√	√	option	partial	HL	Life	37	$755
Tasco	Waterproof #328MW	7.3	51	?	C	BaK4	IF	√	√	√	√	—	Life	52	$990*
Steiner	Admiral Gold	7.0	49	21	FMC	BaK4	IF	√	option	√	√	—	5	37	$1,100*
Zeiss	B Marine	7.6	53	13	FMC	BaK4	IF	√	—	√	√	—	30	44	$1,250
Optolyth	Royal	7.7	54	10	FMC	Roof	CF	√	—	√	—	HL	30	36	$1,300*
10x50 MODELS															
Vivitar	WA #634122	7.0	70	?	C	BK7	CF	√	—	—	—	incl.	10	23	$50
Simmons	WA Red Line	7.0	70	5	C	BK7	CF	√	—	—	—	HV	1	26	$70*
Jason	WA Mercury #1113F	6.5	65	13	C	BK7	CF	√	—	—	—	SV	Life	29	$80*
Orion	WA Observer	7.0	70	9	C	BK7	CF	—	√	partial	—	HV	2	28	$80
Bushnell	Ensign	5.0	50	5	C	BK7	CF	√	—	—	—	incl.	Life	32	$90*
Swift	Aerolite ZCF	7.0	70	10	C	BK7	CF	√	—	—	—	HV	5	27	$90*
Tasco	Wide Angle #2023	7.0	70	?	C	BK7	CF	√	—	—	—	—	Life	26	$90*
Jason	All Terrain #124	7.0	70	16	C	BK7	CF	√	—	partial	—	SV	Life	27	$100*
Orion	Explorer	5.3	53	14	MC	BaK4	CF	√	—	partial	—	HV	5	26	$100
Minolta	Standard	7.8	78	9	MC	BaK4	CF	√	√	√	—	HV	25	35	$110
Simmons	Premium	7.0	70	5	C	BK7	CF	√	—	√	—	HV	Life	28	$110*
Simmons	WA Armored	7.0	70	5	C	BK7	CF	√	—	√	—	HV	Life	27	$115*
Bushnell	Camo Armored	7.0	70	12	C	BK7	CF	√	—	√	—	incl.	Life	29	$130*
Celestron	WA Sport	7.0	70	13	C	BK7	CF	—	√	partial	—	HV	Life	29	$130*
Nikon	Lookout II	6.0	60	9	MC	BaK4	CF	√	—	—	—	incl.	25	29	$130
Nikon	Stayfocus Plus	6.0	60	9	MC	BaK4	CF	√	—	partial	—	incl.	25	30	$140
Bausch & Lomb	Legacy EWA	7.9	79	10	MC	BaK4	CF	√	√	partial	—	incl.	Life	35	$150
Pentax	PCF	6.5	65	8	MC	BaK4	CF	√	√	√	—	SL	Life	31	$150
Bushnell	Spectator	7.0	70	12	C	BK7	CF	√	—	√	—	incl.	Life	26	$160*
Celestron	WA Pro	6.5	65	13	FMC	BaK4	CF	√	√	√	—	HV	Life	29	$160
Selsi	#109	7.0	70	?	C	BK7	CF	√	√	—	—	HV	Life	33	$165*
Mirador	BCF Series	7.0	70	?	C	BaK4	CF	√	√	—	—	HV	Life	25	$170*
Unitron	High Eyepoint #104LE	5.3	53	14	C	BK7	CF	√	—	partial	—	HV	25	26	$170*
Swift	Cougar ZWCF	7.0	70	13	C	BK7	CF	√	√	partial	—	HV	Life	29	$180*
Tasco	World Class	7.0	70	?	C	BK7	CF	√	√	√	—	SV	Life	26	$180*
Tasco	Futura LE	5.3	53	18	C	BK7	CF	√	—	√	—	SV	Life	26	$190*
Unitron	Armored #113BS	7.0	70	?	C	BK7	CF	√	√	partial	—	HV	25	30	$190*
Mirador	ZCF Y-Series	5.0	50	16	MC	BaK4	CF	√	√	—	—	HV	Life	26	$200
Jason	GlassesOn™	6.5	65	17	C	BK7	CF	√	?	√	—	SV	Life	35	$220*
Swift	Audubon BWCF	7.0	70	10	MC	BaK4	CF	√	√	—	—	SV	Life	32	$230
Celestron	Ultima	5.0	50	19	FMC	BaK4	CF	√	√	partial	—	HV	Life	26	$260
Carton	MC Adlerblick	5.0	50	18	FMC	BaK4	CF	√	√	partial	—	HV	20	24	$270
Brunton	Eterna	6.3	63	20	FMC	BaK4	CF	√	—	√	—	SV	Life	33	$300*
Steiner	G Military/Marine	6.3	63	17	FMC	BaK4	IF	√	option	√	√	—	5	36	$400
Redfield	Waterproof	5.0	50	12	C	Roof	CF	√	—	√	√	SV	Life	29	$410*
Optolyth	Alpin	5.1	51	16	FMC	BaK4	CF	√	—	√	—	SL	30	24	$500
aus Jena	B Nobilem	7.5	75	10	FMC	BaK4	CF	√	√	option	partial	HL	Life	40	$550
Mirador	BWCF EXL-Series	7.0	70	13	MC	BaK4	CF	√	√	—	—	incl.	Life	46	$590*
aus Jena	WA Dekaris	7.3	73	?	FMC	BaK4	CF	√	√	option	—	HL	Life	36	$610*
Swarovski	SL Series	5.8	58	5	FMC	BaK4	CF	—	—	√	√	—	Life	36	$650

Manufacturer	Model	Actual FOV (°)	Apparent FOV (°)	Eye Relief (mm)	Coatings	Prisms	Focus Type	Roll Down Cups	Tripod Socket	Armored	Water-proof	Case	Warranty (years)	Weight (oz.)	Retail
8x56 MODELS															
Orion	Sky Explorer	6.0	48	18	MC	BaK4	CF	√	√	√	—	HV	5	37	$150
Celestron	Ultima	6.1	49	17	FMC	BaK4	CF	√	√	partial	—	HV	Life	30	$300
Pentax	DCF	6.5	52	21	MC	Roof	CF	√	√	√	—	SL	Life	41	$400
aus Jena	B Nobilem	6.7	54	16	FMC	BaK4	CF	√	√	—	partial	HL	Life	44	$580
Steiner	MGA Nighthunter	5.7	46	16	FMC	BaK4	IF	√	option	√	√	SV	5	42	$590
Swarovski	SL Series	5.8	46	11	FMC	BaK4	CF	√	—	√	√	—	Life	43	$690
Zeiss	B/GA T* Dialyt	6.3	50	16	FMC	Roof	CF	√	—	√	√	incl.	30	36	$1,170
Optolyth	Royal	6.7	54	10	FMC	Roof	CF	√	—	√	—	HL	30	39	$1,250*
9x63 MODELS															
Pentax	DCF	5.8	52	21	MC	Roof	CF	√	√	√	—	SL	Life	44	$430
Optolyth	Royal	6.1	55	10	FMC	Roof	CF	√	—	√	—	HL	30	42	$1,435*
GIANT MODELS															
10x70															
Orion	Enhanced MC Giant	5.0	50	15	FMC	BaK4	CF	√	√	—	—	HV	5	58	$300
Fujinon	MT-SX Poseidon	5.3	53	12	FMC	BaK4	IF	√	√	—	√	HV	Life	73	$460
Fujinon	FMT-SX Polaris	5.3	53	19	FMC	BaK4	IF	√	√	—	√	HV	Life	76	$590
Nikon	IF-SP Astroluxe	5.1	51	15	FMC	BaK4	IF	√	—	—	√	HV	25	88	$1,000
Unitron	Giant Observation	5.0	50	?	C	BaK4	IF	√	√	—	√	incl.	25	50	$1,040*
16x70															
Fujinon	16x70 FMT-SX Polaris	4.0	64	12	FMC	BaK4	IF	√	√	—	√	HV	Life	76	$650
11x80															
University Optics	Giant	4.5	50	16	FMC	BaK4	CF	√	√	—	—	incl.	30 day	80	$275
Celestron	Giant	4.5	50	16	FMC	BaK4	CF	√	√	—	—	HV	Life	80	$350
Meade	Giant	4.6	51	16	FMC	BaK4	CF	√	√	√	—	HV	Life	79	$360
Orion	MC Giant	4.5	50	16	FMC	BaK4	CF	√	√	—	—	HV	5	77	$370
Parks	Deluxe Giant	4.5	50	?	MC	BPG2	CF	√	√	√	—	HV	Life	80	$400
Unitron	Giant Observation	4.5	50	?	C	BaK4	CF	√	√	—	—	incl.	25	56	$550*
Swift	Observer BCF	4.5	50	16	C	BaK4	CF	√	√	—	—	HV	Life	78	$560*
Mirador	BCF Observation	4.5	50	?	MC	BaK4	CF	√	√	—	—	HV	Life	61	$615*
Bausch & Lomb	Discoverer	4.4	48	12	MC	BaK4	CF	√	√	—	—	incl.	Life	80	$730*
15 and 16x80															
Celestron	15x80 Giant	3.5	53	17	FMC	BaK4	CF	√	√	—	—	HV	Life	80	$360
Orion	16x80 MC Giant	3.5	56	16	FMC	BaK4	CF	√	√	—	—	HV	5	77	$390
Parks	15x80 Deluxe Giant	3.5	53	?	MC	BPG2	CF	√	√	√	—	HV	Life	80	$430
Steiner	15x80 Observer	3.7	55	11	FMC	BaK4	IF	√	√	√	√	option	5	56	$800
Fujinon	15x80 MT	4.0	60	15	FMC	BaK4	IF	—	√	—	√	—	Life	248	$2,650*
20x80															
University Optics	Giant	3.5	70	14	FMC	BaK4	CF	√	√	—	—	incl.	30 day	80	$275
Celestron	Giant	3.5	70	14	FMC	BaK4	CF	√	√	—	—	HV	Life	80	$380
Meade	Giant	3.6	72	12	FMC	BaK4	CF	√	√	√	—	HV	Life	79	$380
Orion	MC Giant	3.5	70	15	FMC	BaK4	CF	√	√	—	—	HV	5	77	$380
Parks	Deluxe Giant	3.5	70	?	MC	BPG2	CF	√	√	√	—	HV	Life	80	$460
Swift	Satellite BWCF	3.5	70	14	C	BaK4	CF	√	√	—	—	HV	Life	80	$570*
Unitron	Giant Observation	3.5	70	?	C	BaK4	CF	√	√	—	—	incl.	25	56	$605*
Mirador	BWCF Observation	3.5	70	?	MC	BaK4	CF	√	√	—	—	HV	Life	61	$640*
Bausch & Lomb	Discoverer	2.7	54	12	MC	BaK4	CF	√	√	—	—	incl.	Life	80	$760*
Miyauchi	BJ-80i	2.5	50	27	FMC	BaK4	IF	√	√	—	partial	option	Life	128	$1,300
100mm and larger															
Orion	14x100 BIF Supergiant	3.3	46	24	C	BK7	IF	√	√	—	—	Metal	5	112	$800
Vixen	20x100 BCF	2.5	50	16	MC	BaK4	CF	√	√	—	—	incl.	Life	116	$900*
Miyauchi	20x100 BJ-100iA	2.5	50	27	FMC	BaK4	IF	√	√	—	partial	option	Life	158	$1,700
Tasco	20x100 Apochromatic	2.5	50	27	FMC	BaK4	IF	√	√	—	√	—	Life	?	$6,100*
Parks	25x100	2.6	65	?	MC	BaK4	CF	—	√	—	—	incl.	Life	208	$1,100
Edmund	25x100 Giant Observation	2.6	65	?	C	BK7	CF	√	√	—	—	Metal	1	140	$1,775
Fujinon	25x150 MT	2.7	67	18	FMC	BaK4	IF	—	√	—	√	—	Life	1000	$9,500*
Fujinon	25x150 EDMT	2.7	67	18	FMC	BaK4	IF	—	√	—	√	—	Life	1000	$11,900*

*Suggested list price. Actual retail prices may be lower. NOTE: Binoculars within each size group listed in order of increasing price.

Editors' Choices — 7x50 Models

While preparing this guide we inspected nearly three dozen pairs of 7x50 binoculars, the type most popular with backyard astronomers. Here are those we found to provide exceptional performances, listed in order of increasing price.

Entry-Level Models (Under $200)

Jason All-Terrain #123 ($95) — Sharp images on-axis and good eye relief. A good performer at low cost. Also available: 10x50 wide-angle.

Minolta Standard ($100) — Multicoated optics with sharp images on-axis, good edge sharpness, wide field, and good eye relief. A solid performer and a best buy. Also available: 10x50 wide-angle.

Orion Explorer ($100) — Multicoated optics with sharp images on-axis. Very light and easy to handle. An excellent performer at low cost. Also available: 10x50. Similar to Unitron 102LE and Tasco Futura.

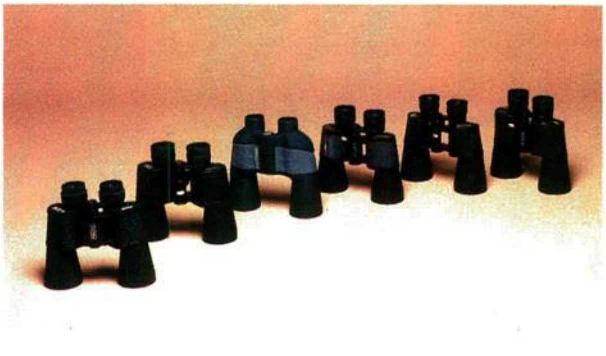
Unitron 102U ($105) — Sharp images on-axis. A good performer at low cost.

Celestron Pro ($150) — Multicoated optics with sharp images on-axis, good edge sharpness, and good eye relief. An excellent moderately priced binocular. Also available: 10x50. Similar to Swift Dolphin.

Selsi Model #108 ($160) — Sharp images on-axis with excellent 18mm eye relief — more than most models in this price class.

Swift Dolphin #703 ($170) — Sharp images on-axis with good eye relief. Focus has useful lock mechanism. Also available: 10x50.

Swift Sea Wolf #713 ($180) — A low-cost waterproof model. Sharp images on-axis, good eye relief, and solid construction. An excellent performer.



CHOICE ECONOMY MODELS in the 7x50 size include (left to right) the Jason All-Terrain, Minolta Standard, Orion Explorer, Celestron Pro, Unitron 102U, and Swift Sea Wolf. Not shown: Selsi 108 and Swift Dolphin.

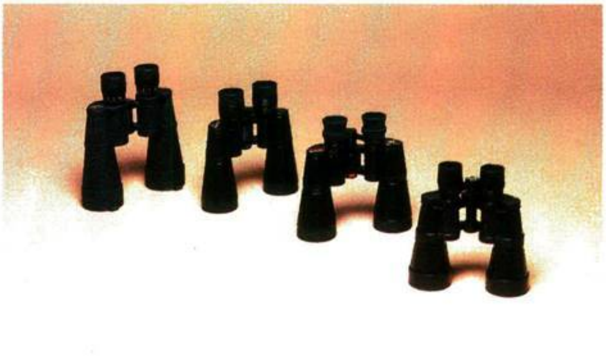
Mid-Priced Models ($200 to $500)

Nikon Windjammer ($270) — Bright, sharp optics with good eye relief. Excellent handling with rubber armoring and waterproof construction. Also available: 7x50 Seasider (yellow finish), 7x50 Stayfocus Plus, 10x50 Lookout II.

Carton Adlerblick ($280) — Bright, sharp optics with good edge sharpness and outstanding eye relief. Very light and easy to handle. Offers superb performance for the money; a best buy. Also available: 7x42, 8x42, and 10x50. Similar to Celestron Ultima.

Celestron Ultima ($280) — Bright, sharp optics with good edge sharpness and good eye relief. Very light and easy to handle. Offers superb performance for the money; a best buy. Also available: 7x42, 10x42, 10x50, and 8x56. Similar to Carton Adlerblick but with slightly less eye relief.

Optolyth Alpin ($490) — Bright, sharp optics with good edge sharpness. Very long eye relief; lightest of all models examined. A wonderfully compact and lightweight armored binocular. Also available: 7x42, 10x50.



TOP-RATED MID-PRICED 7x50s include (left to right) the Nikon Windjammer, Carton Adlerblick, Celestron Ultima, and Optolyth Alpin.

Premium Models (Over $500)

Fujinon FMT-SX ($500) — Very sharp, bright optics with a wide field and outstanding eye relief. Rugged waterproof construction. One of the finest binoculars available for astronomy. Also available: rubber-armored version and 10x70 and 16x70 models.

Swarovski SL-Y ($570) — Very sharp, bright optics with good edge sharpness. Features sculpted ergonomic design and solid waterproof construction. However, eyecups do not fold down — cannot be used with eyeglasses. Requires special Swarovski tripod adapter. Also available: 7x42 (2 models, porro prism and roof prism), 10x50, and 8x56.

Nikon SP-IF Prostar ($650) — Very sharp, bright optics with outstanding edge sharpness. The finest optics of all the 7x50 models we examined — a binocular for those who demand the absolute best. Good eye relief with choice of eyecups. Also available: 10x70 Astroluxe.

aus Jena Nobilem ($740) — Very sharp, bright optics with a rare combination of wide field and excellent eye relief — a binocular for those seeking top-quality optics. Features convenient center focus and is lighter than other premium models. Tripod socket requires special aus Jena adapter. Also available: rubber-armored 7x50, a unique 8x50, and 8x56.

Zeiss (West) Marine ($1,250) — Very sharp, bright optics with one of the widest fields of all 7x50s. Rugged yet compact with waterproof construction. A premium, first-class model. Also available: 7x42 and 8x56.

OFFERING PREMIUM PERFORMANCE in a 7x50 are (left to right) the Fujinon FMT-SX, Swarovski SL-Y, Nikon SP-IF Prostar, aus Jena Nobilem, and Zeiss Marine 7x50B.

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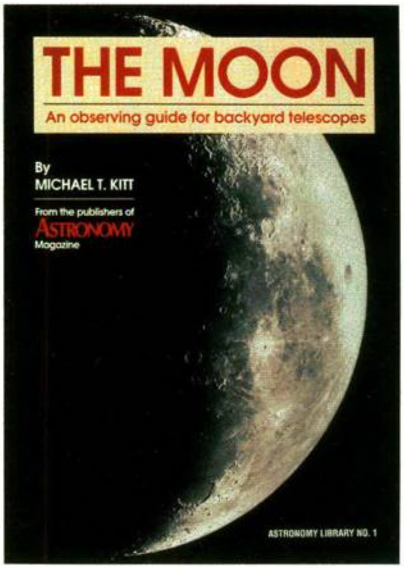
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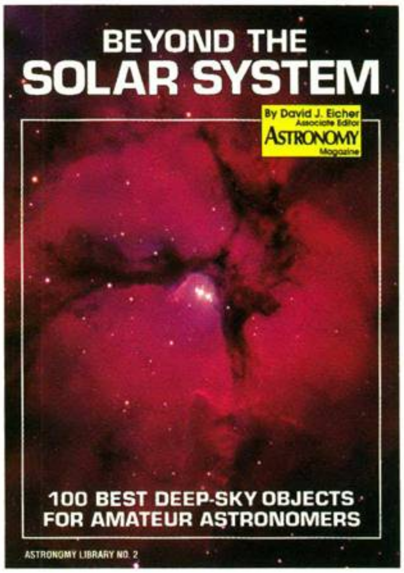
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